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WATER QUALITY MONITORING IN THE BIG THICKET NATIONAL PRESERVE

by

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for

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and

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INTRODUCTION

Public Law 93 - 439 established the Big Thicket National Preserve in October, 1974. The 84,550 acre (34,217.4 hectare) preserve was established "... in order to assure the preservation, conservation and protection of the natural, scenic and recreational values of a significant portion of the Big Thicket area ...."

It is expected that recreational use of the area as well as development outside the units but in the watersheds will increase, and that this will have the potential of altering water quality of streams in the preserve. In 1975 Harrel and Watson summarized past limnological and hydrological research in the vicinity of the preserve, discussed problems that influenced determination of boundaries of the individual units and management decisions of the units, and developed recommendations for future research in the area.

In 1976 Harrel conducted a preliminary limnological survey of streams in the Beech Creek, Turkey Creek, Big Sandy Creek, and Lance Rosier Units, and the Menard Creek Corridor. The objectives of this research were: (1) to determine locations for water quality monitoring stations, (2) to obtain baseline water quality data, (3) to locate existing and potential sites of water pollution, and (4) to develop recommendations for more concise investigations.

In 1976 and 1977 Harrel (1977) and Kost (1977) continued the water quality monitoring program of the streams in the preserve. Selected physico-chemical data were collected on one or two occasions from all stations previously established. Additional sampling sites were established in

streams in the Beech Creek Unit, and were sampled monthly for physicochemical data and benthic macroinvertebrates every two months for one year to determine the effects of recent lumbering activity for pine bark beetle control on water quality.

During the present study physicochemical and bacteriological data were collected from all previously established sampling sites on one or two occasions. Additional monitoring sites were established along the Little Pine Island-Pine Island Bayou Corridor for an intensive one year study of this system. Previous reports (Harrel, 1976 and 1977) stated that these bayous were problem areas and should be studied in more detail. Little Pine Island and Pine Island Bayous receive oil field brines from nearby oil fields and sewage effluent from Pinewood Estates. The communities of Bevil Oaks and Lumberton, located on the banks of Pine Island Bayou, are currently serviced entirely by septic tanks, but are in the process of constructing waste treatment facilities that will release effluents in the Bayou.

Additional objectives of this study were to collect existing publications and data on water quality in the preserve and to write up guidelines for setting up a water quality monitoring system.

The results of the study are presented in two parts; Part I, Water Quality In Little Pine Island and Pine Island Bayous In The Big Thicket National Preserve, which is the Master of Science thesis of Roy G. Darville and Part II, Water Quality of Streams In The Beech Creek, Turkey Creek, and Big Sandy Creek Units and Menard Creek Corridor.

PART I

WATER QUALITY IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS IN THE BIG THICKET NATIONAL PRESERVE

INTRODUCTION

The Big Thicket National Preserve was established in 1974 encompassing 84,550 acres (34,216 ha) in southeast Texas. It is expected that recreational use in the preserve, as well as development outside the preserve but in the preserve units watersheds, will increase, and this will have the potential of altering water quality of streams in the preserve. In order to evaluate water quality changes that may take place, it is necessary to obtain data on present water quality.

Cole (1966), in his review of limnological studies in Texas, did not list a single study on streams in the Big Thicket. A review of limnological and hydrological research in the Big Thicket National Preserve was reported by Harrel and Watson (1975). Harrel (1973, 1975) and Harrel et al. (1976) reported on water quality and benthic macroinvertebrates in the estuarine portion of the Neches River and Pine Island Bayou, some of which is in the preserve. Kost (1977) studied the effects of lumbering on physicochemical conditions and macrobenthos of the Beech Creek Unit of the preserve. Lewis and Harrel (1978) reported on physicochemical conditions and macrobenthos of Village Creek, in which four of the preserve units are within its drainage basin. Harrel (1976, 1977) in project reports for the National Park Service listed some data on water quality of streams in the preserve units and suggested priorities for additional monitoring. In these surveys it was determined that Little Pine Island Bayou, in the Lance Rosier Unit, and the Little Pine Island--Pine Island Bayou Corridor were major problem areas and

should be studied in more detail. Little Pine Island Bayou receives brines from surrounding oil fields and sewage effluent from Pinewood Estates. The communities of Bevil Oaks and Lumberton have plans for construction of waste treatment facilities that will eventually release effluents into Pine Island Bayou.

Many investigators have shown that physicochemical and biological data differ widely when several factors interact to affect water quality. Physicochemical data describes water quality only at the time of sampling, while organisms reflect both present and past conditions.

The use of bacteria as indicators of fecal contamination was first studied by Winslow and Hunnewell (1902). They reported that streptococci bacteria consistently occurred in the feces of all warm-blooded animals and in waters receiving their feces. Presently, the isolation of fecal coliforms or streptococci is used to signify the potential presence of intestinal pathogens. The potential health hazard is dependent on retention of critical density levels and associated virulence of the pathogens over a period of time (McFetters et al., 1974). Gallagher and Spino (1968) stated that pathogenic Salmonella were isolated from fecal coliform densities of less than 150/100 ml after a 99% reduction of fecal coliforms. They recommended fecal coliform levels of 150/100 ml and 750/100 ml be established for contact and non-contact recreational waters. Smith et al. (1973) isolated one Salmonella from an average of 24 fecal coliforms and 109 fecal streptococci. Presently, the Texas Water Quality Board (1976) has standards for contact recreational waters as not to exceed a logarithmic mean fecal coliform content from not less than 5 samples collected over not more than 30 days of 200/100 ml, nor shall more than 10% of the total samples during any

30 day period exceed 400/100 ml.

Geldreich and Kenner (1969) reported that fecal coliforms are more numerous than fecal streptococci in the feces of man with a fecal coliform to fecal streptococcus ratio (FC/FS) always greater than 4. In other warm-blooded animals fecal streptococci are more numerous than fecal coliforms with a FC/FS ratio of 0.7 or less. An intermediate value between 0.7 and 4 is found with a mixture of human and non-human contamination. McFetters et al. (1974) and Feachem (1975) stated that the obvious major weakness of the FC/FS ratio is that it must be assumed that fecal streptococci and fecal coliforms die at identical rates in the aqueous environment. McFetters et al. (1974) reported that coliforms died at slightly faster rates than fecal streptococci in well water. When applying the FC/FS ratio, the unequal die-off rates and all environmental factors of the water must be considered.

Community structure of benthic macroinvertebrates has frequently been used to evaluate water quality and stress in aquatic ecosystems. Keup et al. (1966) pointed out the following characteristics of macrobenthos that make them suitable for detection of subtle changes in water quality and stream conditions: (1) long life cycles, (2) low motility, (3) extreme ranges of tolerance to varying environmental conditions, and (4) central positions in aquatic food chains.

Many investigators have utilized mathematical indices to describe community structure of benthic macroinvertebrates. Perhaps the best accepted of these is Shannon's diversity index ($\bar{d}$), first used by Patten (1962) and later modified by Wilhm (1967) and Wilhm and Dorris (1968). This index equates information to diversity and is a measure of uncertainty regarding the probability of selection of a particular

species from a community. It reflects evenness of species distribution in the community, is dimensionless, and relatively independent of sample size. Clean water communities are characterized by higher $\overline{d}$ values while stressed communities have lower $\overline{d}$ values.

Burlington (1962) proposed a coefficient of similarity (C) to compare faunal similarity between stations. This coefficient can vary from 0 for two stations with no taxa in common to 1 for two stations with identical faunal composition.

The objectives of this study were to obtain baseline water quality data on Little Pine Island and Pine Island Bayous in the Big Thicket National Preserve utilizing physicochemical and bacteriological data and community structure of benthic macroinvertebrates.

DESCRIPTION OF AREA AND SAMPLING STATIONS

Pine Island Bayou originates in eastern Liberty and Polk Counties and flows 93 km southeast through Hardin and Jefferson Counties where it empties into the Neches River. Pine Island drainage basin is within the Beaumont Formation of the Pleistocene and the Alluvial Formation of the Recent period (Barnes, 1968). The substrate consists of sand, silt, and large amounts of colloidal clay (United States Department of Agriculture, 1965). The gradient ranges from 0.85 m/km in the headwaters to 0.28 m/km in the lower reaches. The longest tributary, Little Pine Island Bayou, flows 74 km into Pine Island Bayou at km 19. The drainage basin has oil fields in the vicinity of Saratoga and Sour Lake. The only permitted waste effluent in the area is the municipal sewage outfall from Pinewood Estates into Little Pine Island Bayou. Located in the middle and lower reaches of the basin are the communities of Bevil Oaks and Lumberton that are presently constructing waste treatment facilities and will eventually release waste into Pine Island Bayou. The climate is warm temperate with tropical influences. Precipitation averages 134 cm per year (United States Department of Interior, 1976).

Vegetation along the bayou was defined by Marks and Harcombe (1975) as the flatland-hardwood type and by Watson (1975) as palmetto-hardwood type. Dominant vegetation includes Taxodium distichum (bald cypress), Nyssa sylvatica (blackgum), Liquidamber styraciflua (sweetgum), Quercus spp. (oaks), and Pinus taeda (loblolly pine). Understory

vegetation includes Ilex opaca (American holly), Ilex vomitoria (yaupon holly), Callicarpa americana (American beautyberry), Cornus florida (dogwood), Magnolia virginiana (sweetbay), and Sabal minor (palmetto). There is generally a sparse herb layer present.

Seven sampling stations were established on Little Pine Island Bayou in the Lance Rosier Unit and the Little Pine Island-Pine Island Bayou Corridor of the Big Thicket National Preserve (Figure 1).

Station 1. Located on Little Pine Island Bayou approximately 100 m downstream from Hwy 770 bridge near Saratoga.

Station 2. Located on Little Pine Island Bayou approximately 90 m south of dirt road on Mary Smith land tract near old wood bridge in middle of the Lance Rosier Unit.

Station 3. Located on Little Pine Island Bayou approximately 30 m upstream from Hwy 326 bridge.

Station 4. Located on Little Pine Island Bayou approximately 30 m downstream from the outfall of Pinewood Estates sewage treatment plant.

Station 5. Located on Pine Island Bayou approximately 100 m downstream from convergence of Little Pine Island and Pine Island Bayous.

Station 6. Located on Pine Island Bayou approximately 200 m upstream from Hwy 96 bridge.

Station 7. Located on Pine Island Bayou approximately 100 m downstream from convergence of Village Slough with Pine Island Bayou.

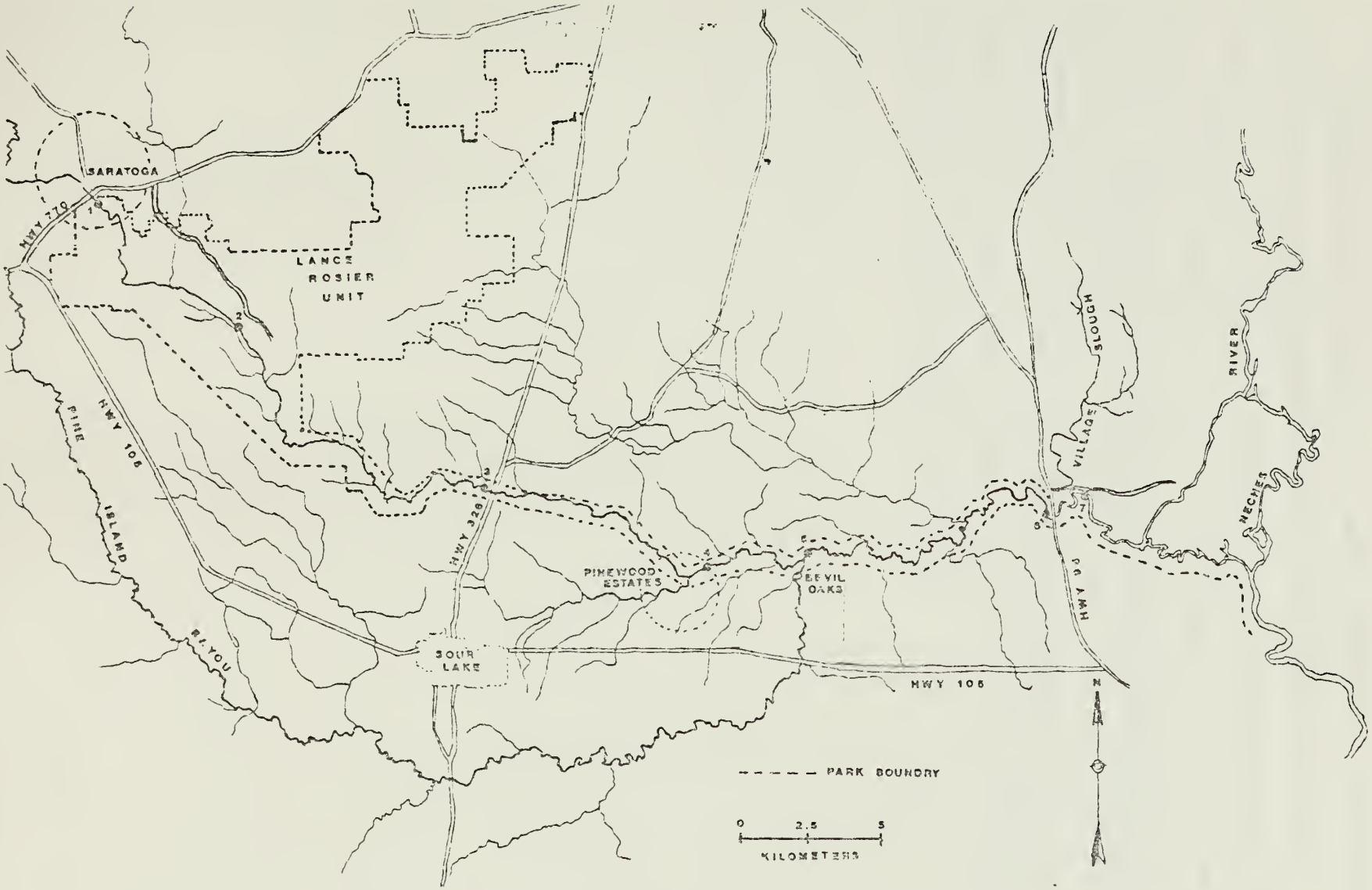


Figure 1. Location of sampling stations

The substrate at Stations 1, 2, and 3 consisted of coarse and fine sand and silt with large amounts of plant detritus due to the closed canopy forest. The substrate at Station 4 was gravel and mud with little plant material. Stations 5, 6, and 7 had substrates of fine sand, mud, and clay. Normal depth varied from less than 0.5 m at Station 1 to a maximum of 7 m at Station 7. At Station 1 water depth and discharge varied extremely during the study with only scattered pools and no discharge during July and August to bank overflow conditions with channel depth of over 1 m during January and February.

METHODS

Samples were taken from June, 1977 to May, 1978 (Table 1). No samples were taken in January because of extreme flooding. Water for determination of physicochemical conditions and bacteria counts was collected at approximately monthly intervals by submerging standard BOD and 100 ml screw top bottles just below the surface. Temperature and dissolved oxygen concentrations were determined at the surface and bottom only at Stations 6 and 7, the only stations with sufficient depth to allow stratification.

Physicochemical data obtained from each station and methods of measurement are listed below:

Water Temperature - Centigrade thermometer or a Yellow Springs Instrument Model 57 Oxygen Meter.

Dissolved Oxygen (O_2) - Azide Modification of the Winkler Method which involves titration with phenylarsine oxide using a starch solution indicator or a Yellow Springs Instrument Model 57 Oxygen Meter.

Oxygen Percent Saturation - Calculation by use of temperature, dissolved oxygen concentrations and tables of oxygen saturation of Truesdale et al. (1955).

Biochemical Oxygen Demand (BOD) - Determination of oxygen concentrations in samples before and after incubation in dark at 20 C for 5 days.

Table 1

Collection Dates

Date	Physicochemical Data	Benthic Data
1977		
June 18	*	
July 17	*	*
August 23	*	
September 17	*	
October 15	*	*
November 12	*	
December 15	*	
1978		
February 2	*	
February 25	*	*
March 18	*	
April 15	*	*
May 11	*	

Carbon Dioxide (CO_2) - Titration with sodium hydroxide standard solution, 0.0227 N, to the phenolphthalein end point.

Alkalinity (Alk) - Titration of 0.020 N sulfuric acid to the brom cresol green-methyl red end point.

pH - Hellige pH Comparator or a Kernco Digital Mini-pH Meter.

Specific Conductance (S Cond) - Lab Line Lectro Mho Meter.

Chlorides (Cl) - The Mohr Argentometric Method which involves titration of a silver nitrate standard solution, 0.014 N, with a chromate indicator.

Turbidity (Turb) - B & L Spectronic "20" Spectrophotometer to obtain transmittance and a turbidity table by Hach Chemical Company (1975).

Apparent Color - Hach Chemical Company DR (Direct Reading) Colorimeter.

Orthophosphate (PO_4) - B & L Spectronic "20" and the Hach Modification of the Ascorbic Acid Method.

Ammonia Nitrogen (NH_4) - B & L Spectronic "20" and the Nessler Method.

Nitrate Nitrogen (NO_3) - B & L Spectronic "20" and the Cadmium Reduction Method.

Iron, Total (Fe) - B & L Spectronic "20" and the 1, 10-Phenanthroline Method.

Total Suspended Solids (TSS) - Use of 0.45μ millipore filters and gravimetric methods.

Total Dissolved Solids (TDS), Total Dissolved Organic Solids (TDO) and Total Dissolved Inorganic Solids (TDI) - Filter sample through 0.45μ millipore filter and evaporate at

103 C in a tared crucible. The residue after evaporation is the TDS. Further burning of the evaporated and weighed sample at 550 C will leave only the inorganic ash (TDI). The weight lost between evaporation and burning is a measure of the organic content (TDO).

Chlorophyll "a" (Chloro) - The method of Richards and Thompson (1952) as modified by Odum et al. (1958) using a B & L Spectronic "20." The chlorophyll is extracted in an acetone solution and the optical density is determined. Chlorophyll "a" concentration in mg/l is calculated by the formula:

$$o.d._{665} \ (13.4) \ \frac{\text{ml of acetone}}{1000 \times \text{liters of } H_2O}$$

Bacteriological data were determined by the membrane filter method (American Public Health Association, 1975). All tests were conducted the same day collected using either 1 or 10 ml water samples filtered through a 0.45μ, gridded, 47 mm millipore filter. The filters were placed on pads saturated with EC media for fecal coliforms or KF Streptococcus media for fecal streptococci and incubated in 47 mm plastic Petri plates. Controls were run using prepared cultures or rat feces dissolved in water. The number of bacterial colonies on each plate was counted after the fecal coliforms were incubated submerged in a water bath at 44.5 C for 24 hours and the fecal streptococci were incubated at 37.5 C for 48 hours. Duplicate samples were done at each station to determine the number of bacteria per 100 ml and the average which was used to calculate the fecal coliform to fecal streptococci (FC/FS) ratio (Geldreich and Kenner, 1969).

Benthic macroinvertebrates were collected seasonally with a petite Ponar dredge (15.24 cm x 15.24 cm). Six samples were taken at each station. Each sample was washed and preserved with formalin in the field and stained with rose bengal dye in the laboratory to facilitate the picking of the organisms (Mason and Yevich, 1967). The samples were later washed in the laboratory in a #30 U. S. Standard Soil Sieve. The organisms were then picked and stored in 70% ethanol until they were identified and counted.

Shannon's index of species diversity ($\bar{d}$) was calculated for each station for each collection and for each station annually using the formula:

$$\bar{d} = -\sum(n_i/n)\ \log_2(n_i/n)$$

where $\bar{d}$ = diversity per individual

n = total number of individuals

n_i = number of individuals of species n_i.

Species diversity calculations were made on Lamar University's Honeywell 6620 computer.

A coefficient of similarity was calculated for each pair of stations using the method of Burlington (1962). A prominence value was calculated for each taxon at each station by multiplying the density of the taxon at a particular station by the square root of the frequency, in percentage, of the taxon at all stations. The coefficient of similarity between any two stations, A and B, was then calculated as follows:

$$C = \frac{2P_1}{P_A + P_B}$$

where C = coefficient of similarity

P_1 = sum of the lowest of the prominence values for each taxon that was common to both stations

P_A = sum of the prominence values for all taxa at Station A

P_B = sum of the prominence values for all taxa at Station B.

PHYSICOCHEMICAL CONDITIONS

Temperature

Temperature varied from 5 C at Station 2 in February to 32 C at Station 7 in July (Table 2, Appendix A). There was generally a downstream trend of increasing temperature with an average increase of 4.5 C from Station 1 to Station 7. These differences can be attributed to differences in shading, water volume, and time of sampling. Thermal stratification existed at Stations 6 and 7 during the spring and summer months with maximum surface to bottom temperature extremes of 4 C at Station 6 in April.

Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved oxygen values ranged from 0.8 ppm (10% saturation) at Station 1 in August to 12.2 ppm (100% saturation) at Station 6 in February (Table 2, Appendix A). The largest annual fluctuation occurred at Station 1, while the least fluctuation occurred at Station 7. Higher concentrations occurred at all stations during the cold months. The lowest concentrations occurred in small isolated pools at Station 1 and in the deeper waters during periods of low flow and thermal stratification at Stations 6 and 7.

Biochemical oxygen demand (BOD) was relatively low at all stations at all times of the year. BOD ranged from 0.1 ppm at Station 4 in October to <10.4 ppm at Station 2 in August in an isolated pool. Station 4, located downstream from the Pinewood Estates sewage treatment

Table 2

Extremes of Physicochemical Conditions, June, 1977 - May, 1978.

Parameter	Station 1	2	3	4	5	6	7
Temperature (C)							
Surface	6-27	5-25	7-25	7-28	7-28	6.5-31	6-32
Bottom						6-29	6-29
D. O. (ppm)							
Surface	0.8-10.5	2.7-11.5	4.3-11.6	4.5-11.6	4.7-11.5	4.8-12.2	5.1-11.8
Bottom						2.1-11.8	1.7-11.6
% Saturation							
Surface	10-91	33-95	57-99	56-107	58-99	53-102	57-124
Bottom						26-105	20-96
BOD (ppm)	1.5-5.6	1.3-<10.4	0.2-4.5	0.1-4.9	1.0-4.5	1.6-5.2	2.0-4.8
CO_2 (ppm)	7.5-18.5	3.5-14.0	3.5-14.5	4.5-16.5	3.5-12.0	3.0-10.5	3.0-12.0
Alkalinity (ppm)	3-35	5-135	5-45	16-215	16-69	11-54	9-59
pH	4.2-6.3	4.9-7.4	5.0-6.9	5.4-7.8	5.2-7.1	5.2-7.2	5.6-7.3
Specific Conductance (μ mhos/cm)	57-3550	78-1470	86-1225	105-1480	41-625	23-365	20-336
Chlorides (ppm)	27.5-1440	31.5-532	35-476	36-460	31-184	30-97.5	30-88.5
Turbidity (JTU)	32-206	47-320	20-140	30-175	88-<395	75-<395	68-<395
Apparent Color (CU)	60-440	110-600	30-290	40-280	170-500	100-500	90-500

Table 2 (Continued)

Parameter	Station 1	2	3	4	5	6	7
PO_4 (ppm)	0.02-1.46	0.01-2.05	0-2.12	0-6.95	0-0.94	0-0.80	0.09-1.21
NH_4 (ppm)	0.67-4.45	0.86-4.05	0.31-2.80	0.48-6.80	1.00-8.45	0.60-3.10	0.54-3.10
NO_3 (ppm)	0-0.45	0-0.75	0-0.95	0-5.24	0-0.40	0-0.40	0-0.45
Fe (ppm)	0.28-2.90	0.40-3.12	0.16-1.46	0.08-1.47	0.60-3.25	0.58-2.22	0.58-2.04
TSS (ppm)	10-115	2-117	2-55	13-65	28-157	10-113	6-156
TDS (ppm)	40-2826	62-1016	48-800	56-860	88-368	48-412	92-200
TDO (ppm)	24-590	54-174	40-202	34-290	26-116	14-128	6-94
TDI (ppm)	2-2236	2-848	8-636	14-754	34-272	10-300	40-160
Chlorophyll "a" (mg/l)	0-0.2948	0-0.2948	0-0.0402	0-0.0429	0-0.268	0-0.0911	0-0.0911

plant outfall, had concentrations which ranged from 0.1 to 4.5 ppm indicating low organic load and effective treatment or the effects of strong chlorine treatment which killed the bacteria which satisfy the BOD.

AGREED! ALSO NO DO DEFICIT BUT DO SOME PLOTTING

Carbon Dioxide, Alkalinity, and pH

Carbon dioxide concentrations generally decreased downstream and varied from 18.5 ppm at Station 1 in May to 3.0 ppm at Station 6 in July and Station 7 in August (Table 2, Appendix A). Seasonally, carbon dioxide concentrations increased from January to April due to increasing temperatures and decay rates.

Only bicarbonate alkalinity was present and concentrations ranged from 3 ppm at Station 1 in February to 215 ppm at Station 4 in July (Table 2). Alkalinity generally increased from Station 1 to Station 4, then decreased to Station 7. The increase from Stations 1 to 4 can be attributed to the influx of oil field brines at Stations 2 and 3 and the Pinewood Estates sewage effluent at Station 4.

The pH was usually lowest at Station 1 and highest at Stations 4 or 7. The pH varied from 4.2 at Station 1 in February to 7.8 at Station 4 in August (Table 2). The low pH values at the upper stations were due to large amounts of decaying plant detritus. The higher pH values at Station 4 were due to the Pinewood Estates sewage effluent.

CONDUCTIVITY / Cl^- BRINES DETECTION

Conductivity and Chlorides

Conductivity and chloride concentrations were directly related and useful for detection of oil field brines from nearby oil fields. Increases in concentrations of these parameters between collections and stations denoted the presence of oil field brines.

Conductivity ranged from 20 μmhos/cm at Station 7 in April to 3550 μmhos/cm at Station 1 in November (Table 2, Appendix A). Chloride concentrations varied from 27.5 ppm at Station 1 in February to 1440 ppm at Station 1 in November.

Conductivity and chloride concentrations indicated the presence of brines coming from upstream into the study area at Station 1 in November, April, and May. Higher than normal concentrations were detected at Stations 2 and 3 during all collections except February. This can be attributed to seepage of brines from the Saratoga Oil Field. Higher than normal concentrations occurred at Station 4 during six collections due to the effluent of Pinewood Estates. During the November and December collections, conductivity and chloride concentrations slightly increased between Stations 4 and 5 indicating the influx of brines from the Sour Lake Oil Field into Pine Island Bayou which flows into the preserve corridor just north of Hwy 105.

Turbidity and Apparent Color

Turbidity varied from 20 JTU at Station 3 in November during low flow to greater than 395 JTU at Stations 5, 6, and 7 in December during high flow (Table 2, Appendix A). During normal discharge Station 5 had the highest turbidity due to colloidal clay in the waters of upper Pine Island Bayou. Turbidity was always lowest at Station 3 due to the presence of brines which precipitated the suspended particles. Turbidity was generally similar at Stations 1 and 2, decreased at Station 3, increased at Stations 4 and 5, and decreased at Stations 6 and 7.

Apparent color ranged from 30 CU at Station 3 in August to 600 CU at Station 2 in August in an isolated pool (Table 2, Appendix A). Higher values were generally found in isolated pools with abundant plant detritus or during high discharge conditions.

Orthophosphate and Total Iron

Orthophosphate concentrations ranged from zero at Stations 3, 4, 5, and 6 during high discharge conditions to 6.95 ppm at Station 4 in August during low flow (Table 2, Appendix A). Orthophosphate concentration was usually higher at Station 4, probably due to detergents in the Pinewood Estates sewage effluent.

Total iron varied from zero at Stations 5 and 7 in September to 3.25 ppm at Station 5 in March (Table 2, Appendix A). Highest concentrations usually occurred at Station 5. No seasonal or downstream trends occurred.

NEED FLOW RATED LOADING ASSESSMENT

Ammonia Nitrogen and Nitrate Nitrogen

Ammonia nitrogen varied from 0.31 ppm at Station 3 in August to 8.45 ppm at Station 5 in May (Table 2, Appendix A). Highest concentrations (greater than 3 ppm) were generally found at Station 1 which had abundant decaying plant material and often low oxygen concentrations.

Nitrate nitrogen varied from zero at all stations during at least one collection to 5.24 ppm at Station 4 in October. No consistent seasonal or downstream trends were noted.

Total Suspended and Dissolved Solids

Total suspended solids varied from 2 ppm at Station 2 in October and Station 3 in September to 157 ppm at Station 5 in March (Table 2, Appendix A). Higher values generally occurred at Station 5,

located below the confluence of Pine Island and Little Pine Island Bayous, or in isolated pools at Stations 1 and 2.

Total dissolved solids varied from 40 ppm at Station 1 in February during flood conditions to 2826 ppm at Station 1 in November. The high value was due to oil field brines denoted by the high concentration of inorganic (2236 ppm) to organic (590 ppm) solids. There was usually a gradual decrease in total dissolved solids downstream. Total dissolved organic solids were generally highest at Stations 1, 2, and 3, which had abundant plant detritus. Total dissolved inorganic solids were generally higher at stations that received oil field brines or at Station 4 below the Pinewood Estates sewage outfall.

Chlorophyll "a"

Chlorophyll "a" concentrations ranged from 0 mg/l at all stations during at least one collection to 0.2948 mg/l at Stations 1 and 2 in October (Table 2, Appendix A). These low concentrations were as expected in a heavily shaded, turbid stream.

WATER QUALITY OF MARGINAL → SATISFACTORY
QUALITY PLOTTING WOULD HAVE ADDED LOTS TO
ASSESSMENT SP COND/ CT GOOD FOR BRINE
SEEPAGE DETECTION. PINEWOOD STP
LOCK LIKE

BIOLOGICAL CONDITIONS

Bacteria

Numbers of fecal coliform bacteria varied from 0/100 ml at all stations, except Stations 1 and 5, during at least one collection to 5880/100 ml at Station 1 in December following heavy precipitation (Table 3). Station 4, located below the Pinewood Estates sewage outfall, had no or very few fecal coliforms except during the September and December collections after heavy rainfalls. The low numbers were probably due to chlorination of the effluent. Station 5, located near the community of Bevil Oaks had high numbers during eight collections. Every station had higher than acceptable numbers for contact recreational sports according to the Texas Water Quality Board (1976) standard of 200/100 ml on at least one occasion.

Numbers of fecal streptococci bacteria ranged from zero during at least one collection at Stations 4 and 7 to 3080/100 ml at Station 2 in July in an isolated pool (Table 3). Lower numbers consistently occurred at Station 4. High numbers of fecal coliforms and fecal streptococci occurred at all stations during December following heavy rains and surface runoff.

The fecal coliform to fecal streptococcus ratio (FC/FS) ranged from zero at all stations, except Station 1, during at least one collection to 337.5 at Station 1 in March during out-of-bank flood condition. According to the FC/FS ratio standards of Geldreich and

Table 3

Numbers of Fecal Coliforms (FC) and Fecal Streptococci (FS) and the FC/FS Ratio

Date		Station 1	2	3	4	5	6	7
June 18, 1977 FLOOD	FC	380	0	0	220	1560	0	0
	FS	200	500	310	190	410	280	410
	FC/FS	1.90	0	0	1.16	3.80	0	0
July 17, 1977 LOW FLOW	FC	190	2700	100	0	0	330	940
	FS	2720	3080	570	150	1110	250	60
	FC/FS	0.07	0.87	0.18	0	0	1.32	15.67
August 23, 1977 LOW FLOW	FC	290	540	10	0	10	0	0
	FS	170	590	140	0	210	50	90
	FC/FS	1.71	0.93	0.04	0	0.03	0	0
September 17, 1977 BANK FULL	FC	110	1450	500	3230	940	600	20
	FS	100	160	810	180	540	250	0
	FC/FS	1.10	9.06	0.62	17.95	1.74	2.40	0
October 15, 1977 LOW FLOW	FC	335	830	85	0	2530	125	1305
	FS	110	165	175	0	205	25	5
	FC/FS	3.04	5.03	0.49	0	12.34	5.00	261.0
November 12, 1977 LOW FLO—	FC	120	195	10	5	490	720	605
	FS	250	235	80	30	160	90	0
	FC/FS	0.48	0.83	0.13	0.17	3.06	8.00	0.
December 15, 1977 FLOOD	FC	5880	900	745	705	795	770	1285
	FS	710	705	1205	875	1095	895	925
	FC/FS	8.28	1.28	0.62	0.81	0.73	0.86	1.39
February 2, 1978 FLOOD	FC	5	0	25	0	5	5	10
	FS	30	10	60	15	185	165	170
	FC/FS	0.17	0	0.42	0	0.03	0.03	0.06
February 25, 1978 FLOOD	FC	5	10	0	0	15	0	10
	FS	5	55	15	10	75	95	10
	FC/FS	1.00	0.18	0	0	0.20	0	1.00
March 18, 1978 HIGH	FC	3375	640	125	0	985	235	200
	FS	10	20	15	15	75	15	15
	FC/FS	337.5	32.0	8.33	0	13.13	15.66	8.00

Table 3 (Continued)

Date		Station 1	2	3	4	5	6	7
April 15, 1978 Low	FC	145	145	95	0	3350	0	0
	FS	120	80	235	45	115	125	0
	FC/FS	1.21	1.81	0.40	0	29.13	0	0
May 11, 1978 Low	FC	95	3120	945	0	4010	730	30
	FS	325	570	130	35	140	55	15
	FC/FS	0.29	5.47	7.27	0	28.64	13.27	2.00

Kenner (1969), of the 84 individual samples 19 were above 4 indicating primarily human contamination and 41 were below 0.7 indicating contamination by warm blooded animals other than humans. All stations had FC/FS ratios above 4 on at least one occasion. Station 5, located near Bevil Oaks, had FC/FS ratios above 4 during six collections. There were generally no seasonal or downstream trends in bacterial numbers or FC/FS ratios except for consistently low numbers and ratios at Station 4 due to the chlorinated sewage effluent. Also, higher numbers of bacteria occurred immediately following rainfall and increased surface runoff.

Benthic Macroinvertebrates

A total of 123 taxa and 15,263 individuals of benthic macroinvertebrates was collected (Table 4, Appendix B). Dominant groups, which constituted 97.0% of the total number of organisms, included oligochaetes (62.3%, 23 sp.), chironomids (22.5%, 31 sp.), gastropods (3.6%, 4 sp.), amphipods (3.0%, 3 sp.), ephemeropterans (2.2%, 6 sp.), pelecypods (1.3%, 6 sp.), ceratopogonids (0.9%, 1 sp.), nematodes (0.7%), coleopterans (0.6%, 6 sp.), and isopods (0.4%, 2 sp.) (Table 5). The dominant organism at all stations, except Station 3, was the oligochaete Limnodrilus hoffmeisteri which constituted 47.3% of the total individuals (Table 4). Other dominant organisms included the oligochaetes Tubifex sp. (7.5%), Branchiura sowerbyi (1.4%), Peloscolex multisetosus (1.4%), the gastropod Amnicola sp. (3.3%), the clam Sphaerium sp. (1.0%), the amphipod Gammarus sp. (2.2%), the mayflies Hexagenia limbata (1.0%) and Caenis sp. (0.9%), and the chironomids Tanytarsus sp. (5.1%), Cladotanytarsus sp. (3.6%), Chironomus sp. (3.1%), Polypedilum sp. (3.1%), and Procladius sp. (2.3%).

Table 4

Numbers of Benthic Macroinvertebrates Collected From
Little Pine Island and Pine Island Bayous

Organism	Station 1	2	3	4	5	6	7
Hydrozoa							
Hydra sp.			4				1
Turbellaria							
Phagocata morgani	1		1				1
Nematoda	23	14	9	4	9	30	
Annelida							
Polychaeta	1						
Oligochaeta							
Nais variabilis	8	9	1		5	11	
Nais simplex		2	1	10		1	
Dero obtusa	4	8	2		1	112	32
Dero nivea	14	8	2		1	29	10
Dero digitata						3	
Pristina longiseta leidyi	8	2	1	1	1		
Pristina breviseta	8	2			12	4	1
Pristina foreli						1	
Pristina aequiseta						2	
Aulophorus borelli	3						
Aulophorus furcatus		101					
Slavina appendiculata		1				1	1
Haemonais waldvogeli						17	
Limnodrilus hoffmeisteri	1324	1285	466	589	593	1914	1028
Tubifex ap.	901	19	83		47	81	8
Branchiura sowerbyi					2	140	69
Aulodrilus pigueti	2		3		36	96	7
Peloscolex multisetosus	141	2	3			28	32
Eclipidrilus sp.	7	5	4	1	20	3	18
Rhynchelmis sp.	85		15	1	2		2
Stylodrilus heringianus						5	1
Enchytraeus sp.	1						
Branchiobdellidae		1					
Hirundinia							
Bactracobdella picta	5		1	1			
Placobdella papillifera						1	
Helobdella elongata						6	8
Dina sp.	1						
Molluska							
Gastropoda							
Ferrissia sp.	10	2	17				3
Amnicola sp.			202	113	111	52	24
Physa sp.		14	1			1	1
Gyraulus sp.		2	1				

Table 4 (Continued)

Organism	Station 1	2	3	4	5	6	7
Pelecypoda							
Sphaerium sp.	16	16	58	18	5	23	17
Pisidium sp.						1	3
Musculium sp.			2				
Eupera cubensis			20		1		3
Rangia cuneata						1	4
Lampsilis anodontoides					2	2	
Uniomerus sp.						1	1
Unidentified Unionidae						1	
Crustacea							
Mysidacea							
Taphromysis louisianae					16	9	2
Isopoda							
Lirceus sp.	3	2	5		2	11	7
Asellus sp.			2		1	5	18
Amphipoda							
Crangonyx ap.	64	17	2		1		
Gammarus sp.	1	41	234	3	31	26	6
Corophium lacustre						20	21
Decapoda							
Palaemonetes kadiakensis	1		9		8		
Procambarus simulans	1	1	1				
Unidentified Astacidae					2	1	
Hydracarina						13	2
Insecta							
Plecoptera							
Perlesta placida			4	5			
Ephemeroptera							
Hexagenia limbata	4	3	118		11	12	4
Caenis sp.		3	42	58	1	17	19
Stenonema sp.		4	28	1			
Baetis sp.		2					
Neocloeon sp.			1		2		
Callibaetis sp.						3	2
Odonata							
Argia sp.		2	3	1			
Dromogomphus spinosus		1	11	2	1		1
Dromogomphus spoliatus	1			1			
Didymops sp.			1				
Libellula sp.	2			2			
Macromia sp.				1			
Tauriphila sp.			1				
Macrothemis sp.							3
Hemiptera							
Limnogonus sp.			1				
Buenoa sp.	1						

Table 4 (Continued)

Organism	Station 1	2	3	4	5	6	7
Ranatra sp.					1		
Unidentified Corixidae		1					
Megaloptera							
Sialis sp.		6	23	9	1	1	2
Trichoptera							
Polycentropus sp.		4	7	1			2
Cyrnellus sp.			1	2			
Oecetis inconspicua			2				2
Agraylea sp.						1	
Cheumatopsyche sp.				1			
Molanna sp.		2	1				
Phylocentropus sp.							3
Coleoptera							
Stenelmis sp.		1	2	4			
Berosus sp.				48			
Dubiraphia sp.		1	22	4	4	1	2
Hydroporus sp.			1			2	1
Dineutus sp.	1						
Hydrocanthus sp.	1						
Diptera							
Chironomus sp.	90	85	1	277	4	8	8
Tanytarsus sp.	50	31	627	27	21	15	7
Cladotanytarsus sp.	1		501	29	6	4	
Micropsectra sp.			21	3	3		
Cryptochironomus sp.	8	24	5	18	12	25	13
Stenochironomus sp.		1	10	2	1		2
Stictochironomus sp.		2					
Parachironomus sp.	2	6	2			1	
Dicrotendipes sp.	21	75	100	6		46	21
Polypedilum sp.	9	13	236	158	14	23	25
Polypedilum fallax			4			6	1
Pedionomus beckae						1	
Paratendipes sp.			1		5	1	
Zenochironomus sp.			4				
Paralauterborniella sp.	1			2	11		
Psectrocladius sp.	6	8	4	2	5	5	1
Procladius sp.	176	85	18	5		32	38
Labrundinia sp.				1			
Ablabesmyia sp.	1		18	1	1	13	21
Paracladopelma sp.				1	1	1	
Tanypus sp.	2	98	4				
Clinotanypus sp.			1		1		1
Larsia sp.			2				
Tribelos sp.	4						
Cryptotendipes sp.		2	8		2	6	
Conchapelopia sp.		4	20	4	2	5	4

Table 4 (Continued)

Organism	Station 1	2	3	4	5	6	7
Chironomini sp. A (Roback)			1				
Epoicocladius sp.			2			2	
Potthastia longimanus			1	3			
Pseudochironomus sp.							1
Coelotanypus sp.						27	41
Chaoborus punctipennis	21					19	9
Palpomyia tibialis	13	47	34	14	12	14	6
Tabanus sp.	2	2	1				
Cecidomyiidae	1				1		1
Tipula sp.		1					
Simulium sp.				103			
Total Number Individauls	3052	2068	3045	1537	1032	2943	1586
Total Number Taxa	48	50	71	43	47	62	58
Annual Species Diversity ($\bar{d}$)	2.60	2.57	3.82	3.09	2.77	2.59	2.66

Table 5

Annual Numbers and Percent Composition of Major Taxonomic Groups at Each Station and All Stations Combined

Group		Station 1	2	3	4	5	6	7	Annual
Nematoda	Number	23	14	9	4	9	30	14	103
	Percent	0.7	0.7	0.3	0.3	0.9	1.0	0.9	0.7
Oligochaeta	Number	2507	1445	581	602	720	2448	1209	9512
	Percent	82.1	69.9	19.1	39.2	69.8	83.2	76.2	62.3
Gastropoda	Number	10	18	221	113	111	53	28	554
	Percent	0.3	0.9	7.3	7.4	10.8	1.8	1.8	3.6
Pelecypoda	Number	16	16	80	18	8	29	28	195
	Percent	0.5	0.8	2.6	1.2	0.8	1.0	1.8	1.3
Isopoda	Number	3	2	7		3	16	25	56
	Percent	0.1	0.1	0.2		0.3	0.5	1.6	0.4
Amphipoda	Number	65	58	236	3	32	46	27	465
	Percent	2.1	2.8	7.8	0.2	3.1	1.6	1.7	3.0
Ephemeroptera	Number	4	12	189	59	14	32	25	335
	Percent	0.1	0.6	6.2	3.8	1.4	1.1	1.6	2.2
Coleoptera	Number	2	2	25	56	4	3	3	95
	Percent	0.06	0.1	0.8	3.6	0.4	0.1	0.2	0.6

Table 5 (Continued)

Group		Station 1	2	3	4	5	6	7	Annual
Diptera	Numbers	408	484	1626	656	102	254	200	3730
	Percent	13.4	23.4	53.4	42.7	9.9	8.6	12.6	24.4
Chironomidae	Number	371	434	1591	539	89	221	184	3429
	Percent	12.2	21.0	52.2	35.1	8.6	7.5	11.6	22.5
Ceratopogonidae	Number	13	47	34	14	12	14	6	140
	Percent	0.4	2.3	1.1	0.9	1.2	0.5	0.4	0.9

The April collection had the highest number of organisms with 4996 individuals, while the October collection had the lowest number with 3172 individuals. Heavy rains and flooding prior to the July and October collections reduced the population density by scouring of the stream bed and spreading the organisms over a greater area. The greatest number of taxa was 42 which occurred at Station 3 in April (Table 6). Station 3 averaged 34 taxa per collection, while Station 4 averaged 20 taxa per collection. The number of individuals at Station 4 varied greatly with the October and April collections containing 82 and 84 individuals, respectively, while the July and February collections had 576 and 795 individuals, respectively. The high numbers in the February collection were due to high densities of L. hoffmeisteri (589), and the black fly Simulium sp. (103). Those two organisms were successfully able to exploit the disturbed habitat during flood conditions. Lewis and Harrel (1978) found that greatly increased discharge apparently favored oligochaetes and was more responsible for changes in community composition than other seasonal factors. Station 5, located just below the confluence of Little Pine Island and Pine Island Bayous, had the lowest number of total individuals. The limiting factors to the community were high levels of turbidity, total suspended solids, and siltation.

Oligochaetes comprised 83.2% of the total individuals at Station 6 and 82.1% at Station 1 (Table 5). However, they comprised only 19.1% of the total fauna at Station 3. The eurytolerant L. hoffmeisteri dominanted. Other important oligochaetes were the eurytolerant Tubifex sp. and gill-bearers Dero spp. and Branchiura sowerbyi. Peloscolex multisetosus was found at all stations except Stations 3 and 4 and composed 4.6% of the total number of individuals at Station 1.

Table 6

Variations of Numbers in Taxa, Individuals, and Species Diversity ($\overline{d}$)

Collection Date		Station 1	2	3	4	5	6	7
June 17, 1977	Taxa	29	29	34	20	22	24	26
	Ind.	350	371	474	576	320	894	281
	$\overline{d}$	2.79	2.75	3.87	2.72	2.19	1.57	2.62
October 15, 1977	Taxa	19	20	32	17	25	36	25
	Ind.	604	736	528	82	291	762	169
	$\overline{d}$	1.61	2.44	3.13	2.75	2.71	2.88	3.23
February 25, 1978	Taxa	17	20	27	26	17	41	40
	Ind.	683	521	306	795	206	625	693
	$\overline{d}$	2.13	1.16	1.94	1.76	1.92	2.85	2.49
April 15, 1978	Taxa	24	19	42	17	20	31	21
	Ind.	1415	440	1737	84	215	662	443
	$\overline{d}$	2.54	2.10	3.29	3.30	2.70	1.93	1.44
Annual	Taxa	48	50	71	43	47	62	58
	Ind.	3052	2068	3045	1537	1032	2943	1586
	$\overline{d}$	2.60	2.57	3.82	3.09	2.77	2.59	2.66

Gastropods were found at all stations and comprised 3.6% of the total number of individuals. The gill-bearing Amnicola sp. was dominant at Station 3, where it composed 6.6% of the individuals. Amnicola sp. was not collected at Stations 1 or 2, probably because of the low oxygen, pH and alkalinity. Bivalves composed 1.3% of the total fauna of all stations. Fingernail clams, dominated by Sphaerium sp., were found at all stations. Rangia cuneata, a brackish-water clam, was found only at Stations 6 and 7. The larvae of R. cuneata requires salt water for a certain period of time in order to develop, so salt water must have been present at these stations in the past.

Crustaceans composed 3.7% of the total fauna. The amphipod Gammarus sp. was found at all stations and composed 7.7% of the total fauna at Station 3. Two brackish-water crustaceans were found at the lower stations: The mysid Taphromysis louisianae was found at Stations 5, 6, and 7, while the amphipod Corophium lacustre was found at Stations 6 and 7.

Mayfly nymphs were dominated by the intolerant, burrowing Hexagenia limbata, which comprised 1.0% of the total fauna and the facultative Caenis sp., which comprised 0.9% of the total fauna. H. limbata has often been used as an indicator of water quality (Fremling, 1970). Harrel and Duplechin (1976), in their marsh bayou study, found H. limbata at all stations except two located just below a sewage outfall. In the present study H. limbata was found at all stations except Station 4 which was just downstream from the Pinewood Estates sewage outfall. It was found in greatest numbers at Station 3 which had the clearest water and received some oil field brines. The facultative, coleopteran larve Berosus sp. was found only at Station 4.

Shannon's species diversity index ($\bar{d}$) ranged from 1.16 at Station 2 in February to 3.87 at Station 3 in July (Table 6). Annual $\bar{d}$ varied from 2.57 at Station 2 to 3.82 at Station 3. All $\bar{d}$ values were depressed in February during high discharge. Lewis and Harrel (1978) found higher $\bar{d}$ values during highest discharge in Village Creek and lower $\bar{d}$ values as the stream returned to normal discharge. Except for Stations 4 and 6, $\bar{d}$ values were generally highest in July. Species diversity in October and April were intermediate and similar except for Station 7, which had a higher $\bar{d}$ value during October and lower during April.

Station 3 had the highest $\bar{d}$ values except during February when a value of 1.94 was obtained during flooding and scouring of the stream bottom. Station 4, located below the sewage outfall, had a $\bar{d}$ value of 3.30 in April when only 84 individuals were collected. The Environmental Protection Agency (1973) stated that caution must be used in interpreting $\bar{d}$ values when the number of individuals is below 100. Species diversity values at this station during July (2.72) and February (1.76) are probably more realistic considering the physicochemical conditions. The low and intermediate $\bar{d}$ values reflect stressed conditions due to physicochemical parameters such as low pH and alkalinity, high turbidity and total suspended solids, and extreme variations of discharge which lowers the stability and diversity of the community.

Burlington's (1962) coefficient of similarity allows the comparison of the faunal similarity between stations. The highest coefficient of similarity was 0.72 between Stations 2 and 7, while the lowest coefficient was 0.26 between Stations 1 and 3 (Table 7). No station was very similar to Station 3, which had the highest $\bar{d}$ values. Station 4 had the highest coefficient with Station 3 (0.42). Stations 1 and 2 were

Table 7

Coefficients of Similarity
For All Pairs of Stations

Station	1	2	3	4	5	6	7
1	----						
2	0.68	----					
3	0.26	0.33	----				
4	0.36	0.27	0.42	----			
5	0.38	0.54	0.40	0.66	----		
6	0.57	0.67	0.37	0.37	0.46	----	
7	0.55	0.72	0.32	0.51	0.60	0.66	----

similar in physicochemical conditions, substrates, and discharge and had a high coefficient (0.68). The high coefficients between Stations 2 and 6 (0.67) and between Stations 2 and 7 (0.72) are difficult to explain, in that they do not resemble each other in physicochemical conditions, substrate, or discharge. Stations 6 and 7 had a high coefficient of 0.66 and were very similar environments.

SUMMARY AND CONCLUSIONS

Water quality of Little Pine Island and Pine Island Bayous was studied from June, 1977 to May, 1978 utilizing physicochemical conditions, bacteriological data, and benthic macroinvertebrates.

Physicochemical Conditions

Temperature - Stream temperature ranged from 5 C to 32 C. Thermal stratification occurred at Stations 6 and 7 during spring and summer.

Dissolved Oxygen - Low dissolved oxygen values of less than 50% saturation were found in isolated pools at Stations 1 and 2 during summer and in the deeper waters at Stations 6 and 7 during thermal stratification. All other stations had concentrations above 50% saturation which is suitable to support a diverse biota.

Biochemical Oxygen Demand - BOD concentrations were low and within the expected range for natural waters of this area. Station 4, located below the sewage treatment outfall, had low BOD values (0.1 - 4.9 ppm) indicating low organic load or effective chlorination.

Carbon Dioxide - CO_2 concentrations were typical of streams in this area with highest values associated with stagnant pools and abundant organic material. Surface waters normally have less than 10 ppm free CO_2 (American Public Health Association, 1975).

Alkalinity - All stations had low alkalinity with bicarbonate being the only source as expected in the low pH. Highest alkalinity occurred at Station 4 below the sewage effluent.

pH - The pH of most inland waters in the United States is between 6.0 and 9.0. The pH values below 6.0 that occurred during this study are not uncommon for this area because of the acid soils in the watershed and the large amount of decaying organic material.

Conductivity - Conductivity values above 200 μmhos/cm are uncommon for this area, and concentrations above 600 μmhos/cm may be limiting to some freshwater populations. The higher values that occurred at Stations 1, 2, 3, and 5 were due to oil field brines. The higher values at Station 4 were due to the sewage effluent.

BRINES — CONDUCTIVITY

Chlorides - Chlorides entered the stream by seepage of oil field brines and from the Pinewood Estates sewage treatment plant. Waters containing 250 ppm may have a detectable salty taste (American Public Health Association, 1975). Concentrations above this level occurred at Stations 2 through 4.

Turbidity - This is a measure of the opaqueness of water due to suspended particles. Pine Island Bayou normally has higher turbidity than other area streams, due to colloidal clay in the watershed. The influx of oil field brines at Stations 1, 2, and 3, and the sewage effluent at Station 4 caused floculation of the clay particles and reduced turbidity.

Apparent Color - Apparent color is due to the interplay of light on suspended and dissolved materials. High color at Stations 1 and 2 was due to dissolved organic materials, such as tannin, from plant decomposition. The high values at the lower stations were due primarily to suspended solids.

Orthophosphate and Nitrate Nitrogen - Phosphates and nitrates enter the water by decomposition of plant and animal material, runoff

from pasture and agricultural lands, and seepage from septic tanks. Normal values of both were obtained, except at Station 4 which received sewage effluent. Station 4 had relatively high phosphate concentrations of 5 occasions with a maximum of 6.95 ppm. Nitrate concentrations above 1 ppm occurred only at Station 4.

Ammonia Nitrogen - Ammonia comes from the decomposition of plant and animal protein and is toxic at relatively low concentrations. It is less toxic in acid than alkaline waters, because it exists in the NH_4 ionic state rather than the NH_3 molecule that is prevalent in alkaline waters. All stations had high values (greater than 2 ppm) on at least one occasion.

Total Iron - Iron enters streams by surface runoff and leaching of rock and soil. Concentrations above 1 or 2 ppm are detectable by taste (American Public Health Association, 1975). Every station had iron concentrations above 1 ppm on at least one occasion.

Total Suspended Solids - This is defined as any material that will not pass through a 0.45μ filter. High suspended solids could be limiting to the aquatic community by increasing turbidity and siltation, which reduces the number of microhabitats. Total suspended solids over 100 ppm occurred at all stations at least once, except Stations 3 and 4.

Total Dissolved Solids - Dissolved solids were highest at stations which received brines or immediately below the sewage effluent.

Chlorophyll "a" - All chlorophyll concentrations were low (below 0.3 mg/l) as expected in a heavily shaded, turbid stream.

Bacteria

Every station had higher than acceptable numbers of fecal bacteria on at least one occasion for contact recreational sports

according to standards of Gallagher and Spino (1968) and the Texas Water Quality Board (1976). Highest numbers were found after heavy rainfall and surface runoff or in isolated pools at Stations 1 and 2.

The FC/FS ratios indicated primarily human contamination in 19 samples (23%) and primarily non-human contamination in 41 samples (48%). Station 5, located near Bevil Oaks, had ratios above 4 on six occasions. Ratios of zero occurred in 18 samples (21%) due to the absence of either fecal coliforms or streptococci. In some of the samples with zero ratios the numbers of bacteria were significant (Table 3). Thus when bacteriological data are examined, both the numbers and the ratios must be considered.

Benthic Macroinvertebrates

Benthic macroinvertebrate studies of area lotic waters are compared with this study on Table 8. Kost (1977) reported on macroinvertebrates of streams in the Beech Creek Unit of the Big Thicket National Preserve. He collected a significantly larger number of taxa (172) than in this study (123) and had higher annual $\bar{d}$ values (4.29 - 4.92). The stream's substrates were composed of fine and medium sand with no colloidal clay and received no waste effluents or brines as was present in Pine Island Bayou. Lewis and Harrel (1978) studied Village Creek, a clean water stream with a sand substrate, found a large number of taxa (143) and had higher annual $\bar{d}$ values (3.21 - 4.93) than occurred in this study. They had higher $\bar{d}$ values (2.73 - 4.05) during periods of highest discharge and attributed it to many taxa being carried into the stem-stream from small tributaries. During the present study lower $\bar{d}$ values (1.16 - 3.19) occurred during the period of highest

Table 8

Comparison of Numbers of Taxa and $\bar{d}$ Values
in Area Lotic Waters. Annual $\bar{d}$ Values Are in Parenthesis.

Stream and Source	Comments	Dates	Taxa	$\bar{d}$
Beech Creek (Kost, 1977)	Clean water	Annual	172	3.22-4.62 (4.29-4.92)
Village Creek (Lewis and Harrel, 1978)	Clean water	Annual	143	0-4.50 (3.21-4.93)
Freshwater Canal (Cover and Harrel, 1978)	Constant Physicochemical Conditions	February & June, 1976	102	4.59, 4.09
Receiving Ditch of Sewage Treatment Plant (Sala et al., 1977)	0.5 km above outfall	Annual	32	0.8-2.25 (2.23)
	0.1 km below outfall		19	0.16-1.44 (1.38)
	3.2 km below outfall		18	0.19-1.49 (1.43)
Hillebrandt Bayou (Harrel and Duplechin, 1976)	3.2 km above sewage outfall	Annual	35	1.07-2.34 (1.79)
	50 m below outfall		37	0.47-1.30 (0.96)
	18.4 km below outfall		39	1.18-1.89 (1.90)
Neches River (Harrel et al., 1976)	Clean water, above salt water barrier	Annual	59	1.81-3.60 (3.27)
	Saltwater intrusion and industrial waste, below salt water barrier		88	0.0-3.65 (1.19-3.89)

Table 8 (Continued)

Stream and Source	Comments	Dates	Taxa	$\bar{d}$
Pine Island Bayou (Harrel et al., 1976)	Above salt water barrier	September, 1967	17	1.95
	Below salt water barrier	September, 1967	6	0.37
Pine Island and Little Pine Island Bayous (Present study)	Oil field brines and sewage outfall	Annual	123	1.16-3.87 (2.57-3.82)

discharge. Many more taxa of insects were present in Village Creek (103) and Beech Creek (120) than in Pine Island Bayou (70), many of which were clean water trichopterans, ephemeropterans, odonates, plecopterans, and chironomids. Cover and Harrel (1978) reported high $\bar{d}$ values (4.54, 4.09) from two benthic collections taken from a clean water canal with constant physicochemical conditions. In the present study the lower $\bar{d}$ values (1.16 - 3.87) may be attributed to extreme variations in physicochemical conditions and discharge.

Sala et al. (1977) in their study of a tertiary sewage treatment system reported $\bar{d}$ values of 2.23 above the sewage outfall, 1.38 at the outfall, and 1.43 below the outfall. Harrel and Duplechin (1976) found similar results in their study of Hillebrandt Bayou, a dredged marsh bayou with a sewage outfall. Above the sewage outfall a $\bar{d}$ value of 1.79 was obtained, while at the outfall the diversity decreased to 0.96 and then increased downstream. In the present study Station 3, above the sewage outfall, had a lower diversity of 3.09. However, no recovery of the stream or increased $\bar{d}$ values occurred at downstream stations probably due to changes in physicochemical parameters below the confluences of Little Pine Island and Pine Island Bayous.

Harrel et al. (1976) studied benthic macroinvertebrates above and below the temporary salt water barriers in Pine Island Bayou and the Neches River. The waters below the barriers were often subjected to intrusion of salt water from the Gulf of Mexico and industrial waste. In Pine Island Bayou they found 17 taxa and a $\bar{d}$ of 1.95 above the barrier. In the Neches River they collected 59 taxa and annual $\bar{d}$ ranged from 1.19 to 3.89. The higher values (above 3.0) occurred at the upriver stations which were subject to shorter periods of salt water intrusion

and less concentrated waste. Their Station 8, located near the confluence of Pine Island Bayou and the Neches River had 43 taxa (seven estuarine) and a $\bar{d}$ of 3.89.

Other studies on effects of oil field brines on diversity of lotic waters are comparable with this study. Mathis and Dorris (1968) studied an Oklahoma stream with a brine outfall with maximum conductivity of 16,000 μmhos/cm. At the outfall 31 taxa were found with an annual $\bar{d}$ value of 2.79. Conductivities in the present study were considerably lower, but similar numbers of taxa and $\bar{d}$ values were found. Harrel and Dorris (1968) studied two turbid intermittent streams that received oil field brines. They found improved stream conditions at a station that received moderate concentrations of brines (conductivity 607 μmhos/cm) as indicated by a decrease in turbidity (147 to 50 JTU) and increases in the $\bar{d}$ value (1.78 to 3.15) and numbers of taxa (44 to 62). In the present study the conductivities at Stations 1 through 4 were similar to Harrel and Dorris's (1968) moderate conductivity. However, lower $\bar{d}$ values were obtained at Stations 1 and 2 probably due to extremes of physicochemical parameters and to the no or low flow conditions which existed much of the year. Station 3 had a higher $\bar{d}$ value than Stations 1 or 2 due to a decrease in turbidity and an increase in productivity. Station 4 had a slightly lower $\bar{d}$ value due to increased turbidity and chlorination of the Pinewood Estates sewage treatment effluent.

The clean water studies (Kost, 1977; Cover and Harrel, 1978; Lewis and Harrel, 1978) were characterized by large numbers of taxa, dominated by pollution intolerant species, and high $\bar{d}$ values. The organically polluted streams studied by Harrel and Duplechin (1976) and Sala et al. (1977) were characterized by low numbers of taxa, dominated

by facultative and pollution tolerant forms, and low $\overline{d}$ values. Pine Island Bayou was characterized by intermediate numbers of taxa and $\overline{d}$ values indicating a moderately stressed benthic community. The benthic community was stressed by high turbidity due to colloidal clay in the drainage basin.

PART II

WATER QUALITY OF STREAMS IN THE BEECH CREEK, TURKEY CREEK, BIG SANDY CREEK UNITS AND MENARD CREEK CORRIDOR

All procedures and methods are the same as listed in Part I of this report. Additional water quality monitoring guidelines are given in Appendix C.

LOCATION OF SAMPLING STATIONS AND RESULTS

BEECH CREEK UNIT

The five stations selected during the 1976 - 1977 survey were sampled on June 11, 1977 during low and no flow conditions (Figure 2).

Station BC 1 - Little Beech Creek, approximately 30 m downstream from north boundry of the unit below the tram road

Station BC 2 - Tributary of Beech Creek, approximately 30 m downstream from dirt road through unit

Station BC 3 - Beech Creek, approximately 40 m upstream from road through unit, about 2.4 km below Odumville bridge

Station BC 4 - Tributary of Beech Creek, approximately 25 m downstream from dirt road through unit, about 0.8 km upstream from confluence with Beech Creek

Station BC 5 - Beech Creek, approximately 40 m upstream from south boundary of unit off road connecting HWY 92 and FR 2992

All physicochemical data were as expected during the extremely dry summer (Table 9). Low oxygen and high turbidity and color concentrations occurred in isolated pools at Station BC 1 and BC 2. No fecal coliform bacteria were found indicating no human contamination (Table 10).

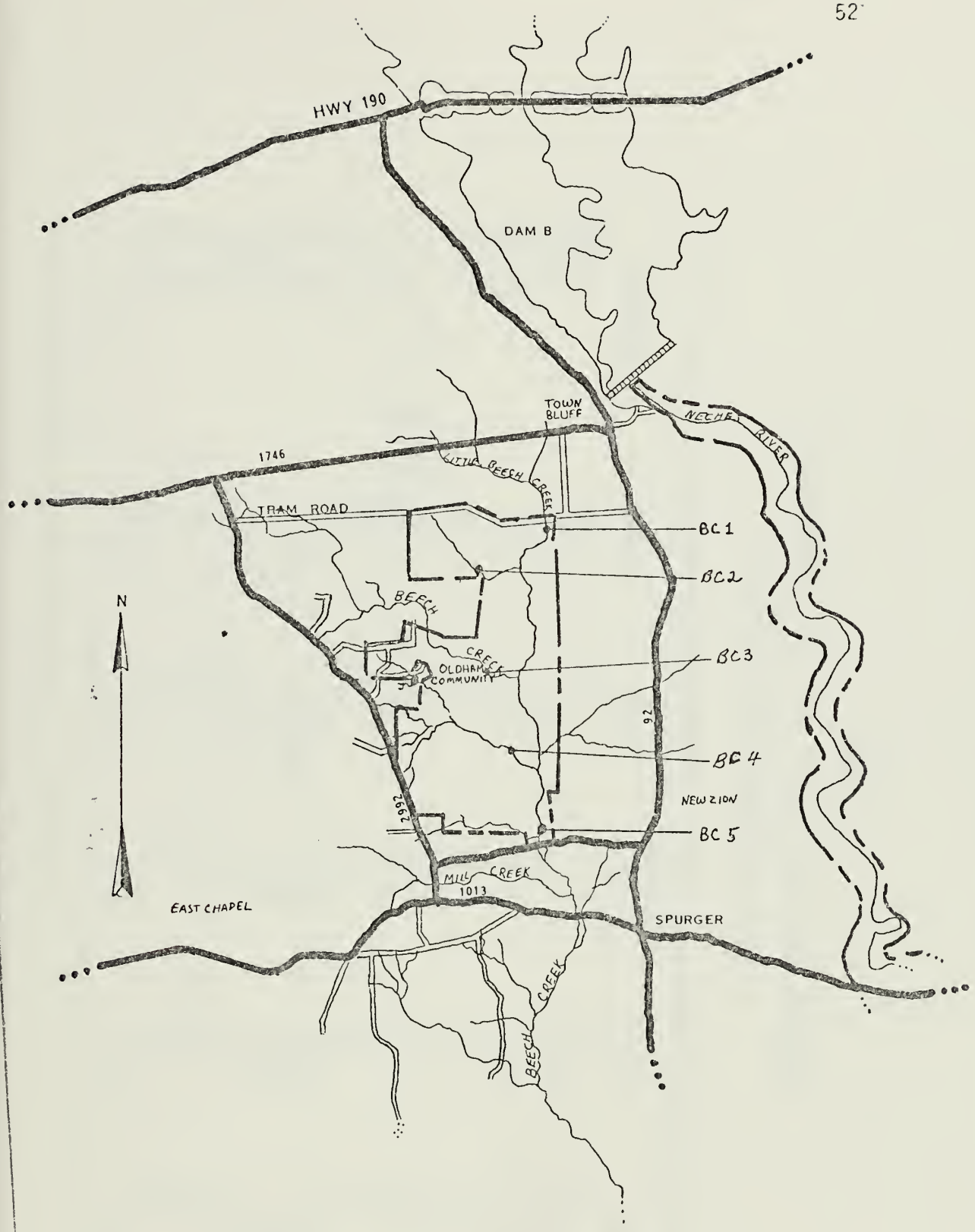


Figure 2. Location of Beech Creek Unit sampling stations.

TABLE 9

PHYSICOCHEMICAL CONDITIONS AT BEECH CREEK UNIT STATIONS

ON JUNE 11, 1977, DURING LOW FLOW *

Parameter	Stations BC 1	BC 2	BC 3	BC 4	BC 5
Temp C	24	22	21.5	22	22
O_2 ppm	3.0	0.25	5.1	4.35	4.0
% Sat	36.0	3	59	51	47
BOD ppm	2.6	4.6	0.9	1.35	1.4
CO_2 ppm	11.5	18.0	10.0	18.0	9.0
Alk ppm	22	43	22	3	22
pH	5.7	5.3	5.8	4.8	5.5
S Cond umhos/cm	74	84	65	51	60
Cl ppm	275	28.0	21.5	25.0	25.0
Turb JTU	175	92	71	56	73
Color CU	480	280	190	160	190
PO_4 ppm	0.50	0.25	0.34	0.46	0.53
NH_4 ppm	3.10	2.12	0.84	0.89	1.03
NO_3 ppm	0.0	0.0	0.25	0.20	0.25
Fe ppm	3.44	3.02	2.04	1.17	1.47
TSS ppm	142	16	18	76	19
TDS ppm	94	86	68	60	74
TDO ppm	32	34	50	60	32
TDI ppm	62	52	18	0.0	42
Chloro mg/1	0.067	0.040	0.027	0.013	0.013

* Only isolated pools existed at Stations BC 1 and BC 2.

TABLE 10

BACTERIOLOGICAL DATA AT BEECH CREEK UNIT STATIONS

ON JUNE 11, 1977, DURING LOW FLOW

Station	Fecal Coliform No./100ml	Fecal Streptococcus No./100ml	FC/FS Ration
BC 1	0	40	0.0
BC 2	0	0	0.0
BC 3	0	210	0.0
BC 4	0	100	0.0
BC 5	0	230	0.0

TURKEY CREEK UNIT

The eight stations sampled during the 1976 and 1977 surveys were sampled on July 25 and July 28 during low flow conditions (Figure 3). Stations TC 1, TC 2, and TC 3 were sampled on July 25 and the remaining stations on July 28. A small rainfall occurred on July 27, thus some surface runoff occurred just prior to the July 28 sampling.

Station TC 1 - Turkey Creek, approximately 25 m downstream from HWY 1943 bridge east of Warren near north boundary of unit

Station TC 2 - Turkey Creek, approximately 30 m downstream from bridge on dirt road west of Pleasant Valley Church

Station TC 3 - Turkey Creek, approximately 25 m upstream from bridge on blacktop road in Hardin County, northeast of Village Mills

Station TC 4 - Turkey Creek, approximately 50 m upstream from confluence with Village Creek

Station VC 1 - Village Creek, approximately 50 m upstream from confluence with Hickory Creek

Station HC 1 - Hickory Creek, approximately 50 m upstream from confluence with Village Creek

Station VC 2 - Village Creek, between confluence of Hickory Creek and Turkey Creek with Village Creek

Station VC 3 - Village Creek, approximately 50 m downstream from confluence with Turkey Creek

All physicochemical parameters were within the normal range for area streams (Table 11). High numbers of fecal coliform bacteria (1450/100 ml) and a FC/FS ratio of 2.04 indicated a mixture of human and non-human contamination in Hickory Creek (Table 12). All stations had fecal streptococcus

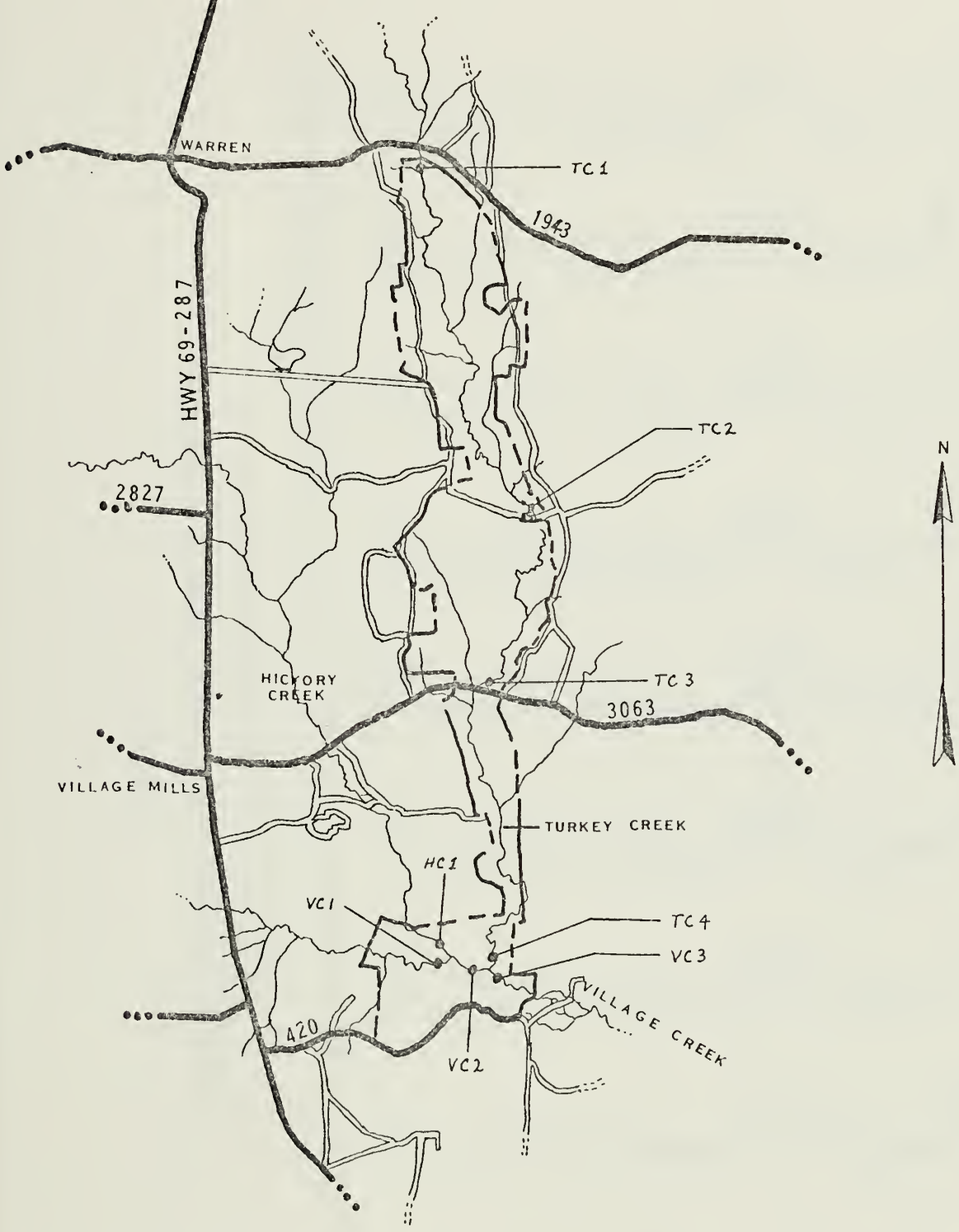


Figure 3. Location of Turkey Creek Unit sampling stations.

1 mi. = 1.61 km

Paved Roads

Dirt Roads

Park Boundary

Waterways

SCALE
2 3 4 MILES

TABLE 11

PHYSICOCHEMICAL CONDITIONS AT TURKEY CREEK UNIT STATIONS

ON JULY 25 and 28, 1977 DURING LOW FLOW

Parameter	Station TC 1	TC 2	TC 3	TC 4	VC 1	HC 1	VC 2	VC 3
Temp C	26	27	27	26	27	26	27	27
O_2 ppm	7.4	7.5	7.8	6.9	6.8	7.0	6.9	6.9
% Sat	93	95	99	86	87	88	88	88
BOD ppm	1.0	1.1	1.8	1.4	1.3	0.3	0.6	0.9
CO_2 ppm	3.5	3.0	4.0	7.0	5.5	4.5	4.0	8.0
Alk ppm	13	11	12	14	13	9	12	12
pH	6.2	5.8	6.1	5.9	5.7	5.4	5.6	5.7
S Cond umhos/cm	69	58	59	59	73	73	72	68
Cl ppm	22.5	23.5	25.0	24.0	25.0	28.5	26.5	24.5
Turb JTU	68	71	71	65	77	68	71	68
Color CU	110	130	130	110	117	120	130	120
PO_4 ppm	0.38	0.52	0.46	0.25	0.14	0.14	0.11	0.18
NH_4 ppm	0.72	0.84	0.72	0.76	0.81	0.74	0.74	0.69
NO_3 ppm	0.185	0.144	0.161	0.114	0.117	0.101	0.107	0.117
Fe ppm	1.02	1.14	1.11	1.02	1.11	0.89	1.02	1.02
TSS ppm	20	17	10	16	30	20	21	20
TDS ppm	108	68	64	48	48	86	58	52
TDO ppm	80	60	48	36	44	54	44	32
TDI ppm	28	8	16	12	4	32	14	20
Chloro mg/l	0.013	0.0	0.0	0.013	0.013	0.013	0.013	0.0

TABLE 12

BACTERIOLOGICAL DATA AT TURKEY CREEK UNIT STATION

ON JULY 25 and JULY 28, 1977 DURING LOW FLOW

Station	Fecal Coliform No./100ml	Fecal Streptococcus No./100ml	FC/FS Ration
TC 1	20	250	0.08
TC 2	0	250	0.0
TC 3	0	190	0.0
TC 4	0	600	0.0
VC 1	40	680	0.06
HC 1	1450	710	2.04
VC 2	70	720	0.10
VC 3	0	520	0.0

bacteria indicating non-human contamination.

BIG SANDY CREEK UNIT

Five stations were sampled on July 7 during low flow conditions and on August 13 during intermediate flow conditions (Figure 4).

Station BS 1 - Big Sandy Creek, approximately 20 m downstream from boundary between the unit and the Alabama-Coushatta Indian Reservation

Station BS 2 - Big Sandy Creek, approximately 100 m downstream from HWY 1276 bridge that crosses the north section of the unit

Station BS 3 - Big Sandy Creek, approximately 20 m downstream from bridge on dirt road near Lily Place, just upstream from confluence of Big Sandy with Double Branch

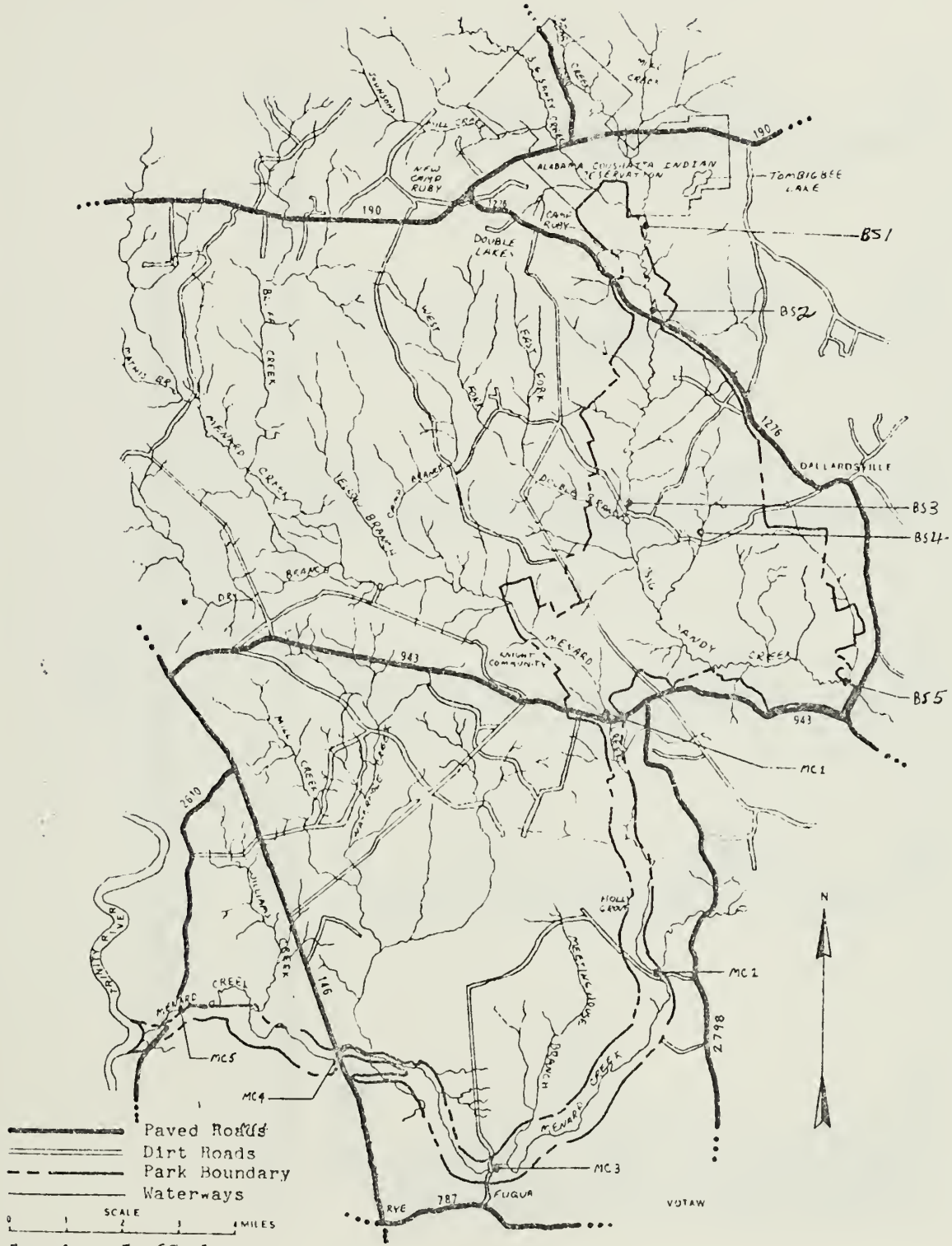
Station BS 4 - Small tributary of Big Sandy, approximately 2.4 km east of Station BS 3, about 10 m upstream from bridge crossing road to Lily Place

Station BS 5 - Big Sandy Creek, approximately 20 m upstream from HWY 1276 bridge near southeast boundary of unit

All physicochemical parameters were normal for area streams (Tables 13 and 14). The bacteriological data indicates non-human contamination (Table 15). Numbers of fecal bacteria were highest at upstream stations and steadily decreased downstream.

MENARD CREEK CORRIDOR

Five Stations were sampled on July 2 and August 8 during low flow conditions (Figure 4).



1 mi = 1.61 km

Figure 4. Location of Big Sandy Unit and Menard Corridor sampling stations.

TABLE 13

PHYSICOCHEMICAL CONDITIONS AT BIG SANDY CREEK UNIT STATIONS

ON JULY 7, 1977, DURING LOW FLOW

Parameter	Stations BS 1	BS 2	BS 3	BS 4	BS 5
Temp C	25	25	25	23	25
O_2 ppm	7.6	7.2	7.2	8.2	7.4
% Sat	94	89	89	98	91
BOD ppm	1.6	0.5	1.0	0.6	0.5
CO_2 ppm	6.0	6.0	5.0	7.5	5.0
Alk ppm	21	25	18	5	14
pH	6.2	5.8	5.5	4.6	5.7
S Cond umhos/cm	84	94	86	32	74
Cl ppm	27.5	27.0	28.5	20.0	29.5
Turb JTU	68	61	61	44	54.
Color CU	125	110	110	70	90
PO_4 ppm	0.20	0.21	0.37	0.42	0.20
NH_4 ppm	0.65	0.46	0.42	0.21	0.42
NO_3 ppm	0.135	0.101	0.080	0.047	0.112
Fe ppm	1.46	1.17	1.17	0.69	1.17
TSS ppm	7	11	45	5	13
TDS ppm	54	60	60	24	54
TDO ppm	48	34	54	6	38
TDI ppm	6	26	6	18	16
Chloro mg/1	0.013	0.013	0.013	0.013	0.013

TABLE 14

PHYSICOCHEMICAL CONDITIONS AT BIG SANDY CREEK UNIT STATIONS

ON AUGUST 13, 1977, DURING INTERMEDIATE FLOW

Parameter	Stations BS 1	BS 2	BS 3	BS 4	BS 5
Temp C	25	25	25	24	25
O_2 ppm	7.2	7.2	6.7	7.8	7.0
% Sat	89	89	83	95	86
BOD ppm	2.5	1.7	2.0	1.3	0.5
CO_2 ppm	4.5	3.5	4.0	11.0	3.5
Alk ppm	7	15	12	3	12
pH	6.1	6.3	6.1	5.4	6.3
S Cond umhos/cm	45	69	55	40	56
Cl ppm	28	30	28.5	26	26.5
Turb JTU	104	95	101	77	68
Color CU	190	90	110	40	40
PO_4 ppm	0.18	0.31	0.32	0.21	0.22
NH_4 ppm	1.64	0.84	1.22	0.94	0.59
NO_3 ppm	0.053	0.097	0.060	0.017	0.053
Fe ppm	1.27	1.31	1.20	0.64	1.11
TSS ppm	18	111	24	13	6
TDS ppm	56	54	38	40	54
TDO ppm	40	28	16	18	28
TDI ppm	16	26	22	22	26
Chloro mg/1	0.013	0.013	0.013	0.013	0.013

TABLE 15

BACTERIOLOGICAL DATA AT BIG SANDY CREEK UNIT STATIONS ON JULY 7, DURING LOW FLOW and AUGUST 13, 1977, DURING INTERMEDIATE FLOW

Station	Fecal Coliform No./100ml 7/7	8/13	Fecal Streptococcus No./100ml 7/7	8/13	FC/FS Ration 7/7	8/13
BS 1	100	1880	1110	3050	0.09	0.62
BS 2	170	570	580	2630	0.30	0.22
BS 3	0	680	110	2100	0.0	0.32
BS 4	20	110	210	660	0.10	0.17
BS 5	0	20	220	300	0.0	0.07

Station MC 1 - Menard Creek, approximately 30 m downstream from bridge crossing FR 943 west of Segno

Station MC 2 - Menard Creek, approximately 40 m downstream from bridge on Holly Grove Cemetery Road of FR 2798

Station MC 3 - Menard Creek, approximately 50 m upstream above bridge on Fuqua - Hoop 'n Holler Road of HWY 105 - 787

Station MC 4 - Menard Creek, approximately 20 m downstream from bridge crossing HWY 146

Station MC 5 - Menard Creek, approximately 30 m downstream from bridge crossing HWY 2610

All physicochemical parameters were considered normal for this stream (Tables 16 and 17). As noted in the 1977 survey, there was a trend toward increased concentrations of alkalinity, pH, chlorides, specific conductance, and TDS downstream as the channel cut deeper into the calcareous substrate nearer the Trinity River.

The FC/FS ratio of 0.71 indicates a mixture of human and non-human bacterial contamination at Station MC 3 on July 2 (Table 18). FC/FS ratios above 4, indicating human contamination occurred at Stations MC 2, MC 4, and MC 5 during the August collection. Stations MC 2, MC 3, and MC 5 were located at or just downstream from often used swimming holes. The area between Stations MC 3 and MC 4 is heavily developed for recreation and real estate and is served entirely by septic tanks.

SUMMARY OF SUMMER, 1977 WATER QUALITY DATA

Physicochemical and fecal bacteriological data were collected from streams in the Beech Creek, Turkey Creek, and Big Sandy Creek Units and Menard Creek Corridor from June 11, 1977 to August 13, 1977. All Streams

TABLE 16

PHYSICOCHEMICAL CONDITIONS AT MENARD CREEK CORRIDOR STATIONS ON JULY 2, 1977, DURING LOW FLOW

Parameter	Stations MC 1	MC 2	MC 3	MC 4	MC 5
Temp C	24	24	24	27	26.5
O_2 ppm	5.7	6.4	6.8	7.8	7.6
% Sat	69	78	82	99	96
BOD ppm	0.8	0.5	0.9	1.9	1.2
CO_2 ppm	6.5	9.5	6.5	6.0	5.0
Alk ppm	14	14	11	13	21
pH	4.9	5.3	5.3	5.7	5.9
S Cond umhos/cm	79	67	79	155	160
Cl ppm	32	30	32	52.5	53.5
Turb JTU	75	49	44	42	47
Color CU	150	90	80	80	80
PO_4 ppm	0.13	0.15	0.07	0.07	0.18
NH_4 ppm	0.84	0.44	0.33	0.38	0.38
NO_3 ppm	0.4	0.7	0.5	0.4	0.4
Fe ppm	1.97	1.14	1.02	0.94	0.94
TSS ppm	9	3	2	6	8
TDS ppm	70	56	68	96	96
TDO ppm	40	18	20	20	20
TDI ppm	30	38	48	76	76
Chloro mg/l	0.013	0.013	0.013	0.013	0.013

TABLE 17

PHYSICOCHEMICAL CONDITIONS AT MENARD CREEK CORRIDOR STATIONS
ON AUGUST 8, 1977, DURING LOW FLOW

Parameter	Stations MC 1	MC 2	MC 3	MC 4	MC 5
Temp C	26	25	25	28	28
O_2 ppm	6.0	6.5	5.8	7.5	8.6
% Sat	75	80	72	97	111
BOD ppm	0.3	0.2	0.0	0.7	1.5
CO_2 ppm	5.5	9.0	7.5	5.0	3.5
Alk ppm	12	11	13	12	21
pH	6.2	5.4	5.9	6.2	7.1
S Cond umhos/cm	59	61	68	165	173
Cl ppm	28.5	30.5	30.5	62.0	61.0
Turb JTU	49	42	39	39	44
Color CU	110	80	70	60	70
PO_4 ppm	0.29	0.31	0.42	0.73	0.31
NH_4 ppm	0.54	0.35	0.30	0.30	0.28
NO_3 ppm	0.074	0.166	0.107	0.080	0.101
Fe ppm	1.24	0.87	0.73	0.67	0.67
TSS ppm	2	14	3	165	7
TDS ppm	60	68	88	122	130
TDO ppm	34	36	32	52	86
TDI ppm	26	32	56	70	44
Chloro mg/l	0.0	0.0	0.0	0.0	0.0

TABLE 18

BACTERIOLOGICAL DATA AT MENARD CREEK CORRIDOR STATIONS

ON JULY 2 and AUGUST 8, 1977, DURING LOW FLOW

Station	Fecal Coliform No./100ml 7/2	8/8	Fecal Streptococcus No./100ml 7/2	8/8	FC/FS Ration 7/2	8/8
MC 1	0	50	4310	300	0.0	0.17
MC 2	50	490	280	110	0.18	4.45
MC 3	100	10	140	160	0.71	0.06
MC 4	0	1980	170	70	0.0	28.29
MC 5	0	1500	0	330	0.0	4.55

were sampled during low flow conditions except the August Big Sandy Creek collection, which had intermediate flow conditions. Low flow is defined as the condition when the channel is less than one-half bank full. Intermediate flow is defined as the condition when all water is confined within the channel and being one-half or more bank full. The following is a brief summary of each of the water quality parameters measured:

Temperature - Stream temperature ranged from 21.5 C to 28 C. Variations within a single stream during the same sampling period was due to time of sampling and the amount of shading.

Dissolved Oxygen - Low oxygen concentrations of less than 50 percent saturation occurred only in Beech Creek at stations with low or no discharge and abundant organic material.

Biochemical Oxygen Demand - BOD concentrations ranged from 0.0 ppm to 4.6 ppm in an isolated pool at Station BC 2 in Beech Creek. All values were within the range expected in natural waters.

Carbon Dioxide - CO_2 concentrations above 10 ppm may be limiting to some aquatic populations if they exist for an extended period of time. CO_2 concentrations higher than 10 ppm were observed at four stations in the Beech Creek Unit and at Station BS 4 in the Big Sandy Creek Unit.

Alkalinity - All streams had low alkalinity with bicarbonate being the only source. Highest alkalinity occurred at Stations MC 4 and MC 5 in Menard Creek associated with a change in substrate.

pH - All streams had low pH values due to the acid soils in the watersheds and the large amount of decaying organic material. The pH ranged from 4.6 to 7.1. The only value above 6.3 occurred at Station MC 5 in Menard Creek.

Specific Conductance and Chlorides - All streams had low concentrations. Highest concentrations occurred at Stations MC 4 and MC 5 in Menard Creek, but these are not limiting to freshwater populations.

Turbidity and Apparent Color - Concentrations of both parameters were normal for area streams. The highest concentrations occurred in an isolated pool at Station BC 1 that was covered with a bacterial slime.

Orthophosphate and Nitrate Nitrogen - All concentrations low and less than 1.0 ppm.

Ammonia - Limiting concentrations above 2 ppm occurred in isolated pools at Stations BC 1 and BC 2 in Beech Creek.

Iron - All streams had iron concentrations above 1 ppm which is the taste threshold.

Total Suspended and Dissolved Solids - All concentrations were low and normal for area sand substrate streams.

Chlorophyll "a" - All concentrations were low as expected in flowing, shaded streams.

Fecal Bacteria - Fecal bacteria were found in all streams and at all stations except BC 2 in Beech Creek in a small isolated pool. FC/FS ratios higher than 4, indicating primarily human contamination, occurred at three stations in Menard Creek. FC/FS ratios higher than 0.7 but less than 4.0, indicating a mixture of human and non-human contamination, occurred in Menard Creek and Hickory Creek in the Turkey Creek Unit. Significant numbers of fecal coliform bacteria (more than 100/100 ml) occurred in Big Sandy Creek, Menard Creek, and in Hickory Creek.

RECOMMENDATIONS FOR FUTURE RESEARCH AND MANAGEMENT

Water quality monitoring should be continued in all streams in the preserve in order to obtain more baseline data and to determine effects of preserve use and development in the watersheds.

Priority should be given to intensive year-long studies of physico-chemical conditions, bacteria, and benthic macroinvertebrates. Intensive year-long surveys allows determination of downstream trends and seasonal extremes with various discharge and climatic conditions. Knowledge of community structure of benthic macroinvertebrates will be most useful in determination of water quality changes. Physicochemical and bacteriological data indicate conditions that exist only at the time of sampling. Benthic macroinvertebrates reflect present and past conditions due to their relatively long life cycles and non-motility. Benthic organisms occupy central positions in the food web, thus they reflect trophic structure at lower and higher levels. The ranges of tolerance to various environmental conditions are known for most taxa.

Intensive year-long surveys have been completed in streams in the Beech Creek Unit and in Little Pine Island and Pine Island Bayous. Streams remaining to be intensively studied are Menard Creek, Big Sandy Creek, and Turkey Creek.

Periodic monitoring should continue in streams located near oil fields (Lance Rosier and Turkey Creek Units), developed and developing real estate areas (Little Pine Island and Pine Island Bayous and Menard Creek), and streams known to receive waste effluents (Little Pine Island and Pine Island Bayous).

Analyses of herbicides and pesticides should be made in Pine Island Bayou and lower Menard Creek before, during and after the rice growing season.

If burning is used as a land management procedure, it would be desirable to take water samples before burning, immediately after burning and at a later date to determine the effects on water quality.

All cattle should be removed from the preserve, especially the Big Sandy Creek Unit, in order to decrease fecal bacteria contamination and allow growth of vegetation in over-grazed areas which effects the rate of surface runoff.

Construction of roads, trails and other tourist facilities within the preserve should be planned so they will not alter drainage patterns or cause erosion and siltation.

No lumbering should be allowed in the preserve. However, if cutting is required for pine bark beetle control it should be on a cut-and-leave basis, with no trees left in the stream channels.

APPENDIX A

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON JUNE 18, 1977, DURING FLOOD CONDITIONS

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	25	25	25	26.5	26	26	26
Bottom						*	*
O_2 ppm							
Surface	5.1	5.8	5.5	5.1	4.9	5.1	5.1
Bottom						*	*
% Sat							
Surface	63	72	68	64	61	64	64
Bottom						*	*
BOD ppm	1.5	1.9	1.8	1.9	2	2.1	2.3
CO_2 ppm	11.5	5.5	9	10.5	9	10.5	9.5
Alk ppm	10	9	5	19	21	15	16
pH	4.5	4.9	5.0	5.4	5.2	5.2	5.6
S Cond μmhos/cm	66	110	102	149	102	86	84
Cl ppm	29	41	44	44.5	32	30	30
Turb JTU	88	80	75	71	95	101	97
Color CU	180	200	290	220	230	300	300
PO_4 ppm	0.13	0.12	0.11	0.13	0.16	0.08	0.11
NH_4 ppm	2.76	2.49	2.19	2.26	2.00	2.33	2.40
NO_3 ppm	0.45	0.75	0.95	0.40	0.40	0.40	0.45
Fe ppm	0.78	0.56	0.43	0.43	0.60	0.58	0.58
TSS ppm	84	12	55	14	38	40	29
TDS ppm	66	106	98	82	88	48	92
TDO ppm	52	66	64	34	54	38	52
TDI ppm	14	40	34	48	34	10	40
Chloro mg/l	0.0	0.013	0.013	0.013	0.013	0.013	0.013

* Parameters not measured due to mechanical failure

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON JULY 17, 1977, DURING LOW FLOW*

Parameters	Station 1	2	3	4	5	6	7
Temp C							
Surface	23	25	25	28	27	31	32
Bottom						29	29
O_2 ppm							
Surface	1.8	3	4.6	7.1	5.8	7.2	9.1
Bottom						3.6	6.5
% Sat							
Surface	21	37	57	92	74	97	124
Bottom						47	85
BOD ppm	5.6	4.0	0.2	0.8	1.3	2.1	2.3
CO_2 ppm	12.5	11.5	9	12.5	8.5	3	3.5
Alk ppm	19	24	29	215	34	19	18
pH	4.7	5.6	5.9	7.2	6.5	6.6	6.9
S Cond μmhos/cm	89	480	340	1420	194	181	182
Cl ppm	30	145	87	377.5	43	45	49
Turb ppm	206	68	59	84	134	81	86
Color CU	440	160	80	110	200	140	280
PO_4 ppm	0.57	2.05	2.12	0.94	0.94	0.61	1.21
NH_4 ppm	3.12	1.36	0.52	1.51	1.40	0.67	0.65
NO_3 ppm	0.08	0.06	0.101	0.032	0.2	0.017	0.017
Fe ppm	2.62	0.65	0.37	0.76	1.46	0.76	0.84
TSS ppm	115	17	16	34	80	32	29
TDS ppm	42	268	224	812	154	92	102
TDO ppm	24	54	62	116	42	14	6
TDI ppm	18	214	162	754	112	78	96
Chloro mg/l	0.054	0.067	0.013	0.013	0.013	0.027	0.04

* Only isolated pools existed at Stations 1 and 2

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON AUGUST 23, 1977, DURING LOW FLOW*

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	27	25	25	27	28	29	28.5
Bottom						**	**
O_2 ppm							
Surface	0.8	2.7	5	5.5	5.25	5.3	7.6
Bottom						**	**
% Sat							
Surface	10	33	62	70	68	69	99
Bottom						**	**
BOD ppm	2.6	<10.4	0.7	0.6	2.15	1.7	4.2
CO_2 ppm	13.5	12.5	7	10.5	11.5	5	3
Alk ppm	35	135	45	172	60	54	45
pH	6.3	7.4	6.3	7.8	6.8	6.5	7.1
S Cond μmhos/cm	148	545	290	870	368	268	247
Cl ppm	31	116	117.5	195.5	77	64	69.5
Turb ppm	128	320	84	106	157	106	101
Color CU	260	600	30	80	180	100	90
PO_4 ppm	0.21	0.21	0.11	6.95	0.12	0.11	0.12
NH_4 ppm	2.19	4.05	0.31	6.80	1	0.6	0.54
NO_3 ppm	0.0	0.0	0.039	0.127	0.074	0.017	0.0
Fe ppm	2.04	3.12	0.26	0.34	1.05	0.69	0.78
TSS ppm	25	117	13	19	48	10	6
TDS ppm	128	404	176	526	242	172	178
TDO ppm	112	174	46	128	82	70	78
TDI ppm	16	230	130	399	160	102	100
Chloro mg/l	0.067	0.268	0.0134	0.0134	0.0268	0.0268	0.067

* Only isolated pools existed at Stations 1 and 2

** Parameters not measured due to mechanical failure

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND
PINE ISLAND BAYOUS ON SEPTEMBER 17, 1977, DURING BANK FULL FLOW

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	23	25	25	26	26	29	30
Bottom						26	27
O_2 ppm							
Surface	3.8	4.75	5.1	4.5	5	6.7	7.4
Bottom						2.1	2
% Sat							
Surface	45	59	63	56	63	88	98
Bottom						26	25
BOD ppm	2.2	6.0	1.4	1.6	1.4	2.9	2
CO_2 ppm	15	10.5	8.5	6	7.5	3.5	3
Alk ppm	4	10	9	24	45	33	37
pH	5.3	6.1	5.9	6.5	6.5	7.2	7.3
S Cond μmhos.cm	105	1060	1225	590	252	272	336
Cl ppm	39	350	355	170	67	71	88.5
Turb JTU	106	64	47	88	123	114	77
Color CU	270	140	80	160	280	220	150
PO_4 ppm	0.03	0.08	0.0	0.0	0.0	0.11	0.09
NH_4 ppm	2.33	1.29	0.89	1.09	2.06	1.36	1.06
NO_3 ppm	0.008	0.032	0.017	0.032	0.0	0.017	0.0
Fe ppm	1.31	1.29	0.89	0.08	1.14	1.05	0.67
TSS ppm	35	4	2	34	78	34	12
TDS ppm	190	696	800	354	160	178	190
TDO ppm	100	138	202	98	116	100	76
TDI ppm	90	558	598	256	44	78	114
Chloro mg/l	0.0134	0.0188	0.0161	0.0429	0.0322	0.0911	0.0911

APPENDIX A (CONTINUED)

PHYSIOCOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON OCTOBER 15, 1977, DURING LOW FLOW*

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	12.5	13	14	18	18.5	24	24.5
Bottom						22	22
O_2 ppm							
Surface	6.8	7	8.9	8.9	9	5.1	7.4
Bottom						3.2	1.7
% Sat							
Surface	66	69	89	97	99	62	90
Bottom						38	20
BOD ppm	1.8	2.4	1	0.1	3.8	2.9	3.8
CO_2 ppm	8.5	5.5	4.5	8.0	4.0	6.0	5.5
Alk ppm	11	40	37	142	64	32	31
pH	5.8	6.8	6.8	7.7	7	6.3	6.3
S Cond μmhos/cm	330	890	440	875	510	365	273
Cl ppm	130	285	135	227.5	135.5	97.5	67.5
Turb JTU	42	65	26	30	101	75	68
Color CU	75	140	50	40	220	107	160
PO_4 ppm	0.02	0.01	0.03	6.9	0.45	0.11	0.16
NH_4 ppm	0.67	1.09	0.37	0.48	1.36	1.32	1.18
NO_3 ppm	0.025	0.008	0.039	5.24	0.08	0.017	0.0
Fe ppm	0.43	0.58	0.22	0.25	1.46	0.97	0.92
TSS ppm	52	2	5	13	43	23	30
TDS ppm	214	530	256	552	272	222	192
TDO ppm	76	102	70	112	108	68	32
TDI ppm	138	428	186	440	164	154	160
Chloro mg/l	0.2948	0.2948	0.0134	0.0134	0.0201	0.0248	0.0335

* Only isolated pools existed at Station 1

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON NOVEMBER 12, 1977, DURING LOW FLOW

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	9	9	10	13	13	19	19
Bottom						18	18
O_2 ppm							
Surface	6.3	7.3	8.3	8.3	7.4	4.8	5.1
Bottom						2.8	4.1
% Sat							
Surface	56	65	76	81	73	53	57
Bottom						31	45
BOD ppm	2.2	3.4	3.2	1.2	1.0	5.2	3.2
CO_2 ppm	13	3.5	3.5	6	6.5	8.5	7.5
Alk ppm	12	31	44	74	69	43	59
pH	6.1	6.7	6.9	7.1	7.1	6.5	6.4
S Cond μmhos/cm	3550	610	310	430	490	253	290
Cl ppm	1440	100	95	127.5	140.5	65	74
Turb JTU	32	47	20	68	88	80	68
Color CU	60	110	50	140	170	150	120
PO_4 ppm	0.11	0.18	0.21	2.4	0.57	0.31	0.21
NH_4 ppm	1.03	0.86	0.31	1.15	1.22	1.06	1.03
NO_3 ppm	0.025	0.008	0.017	1.048	0.127	0.275	0.091
Fe ppm	0.28	0.4	0.16	0.73	1.14	0.76	0.84
TSS ppm	11	10	2	14	28	19	12
TDS ppm	2826	416	425	268	292	168	200
TDO ppm	590	82	50	102	50	74	46
TDI ppm	2236	334	375	166	242	94	154
Chloro mg/l	0.0	0.0134	0.0134	0.0067	0.0067	0.0248	0.0255

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND
PINE ISLAND BAYOUS ON DECEMBER 15, 1977, DURING FLOOD CONTITIONS

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	12	12	13	13	13.5	14	14
Bottom						13	13.5
O_2 ppm							
Surface	9.5	9.9	9.8	10.1	9.7	9.9	9.8
Bottom						9.9	9.4
% Sat							
Surface	91	95	96	99	96	99	98
Bottom						97	93
BOD ppm	5	4.3	4.5	4.9	4.2	4.8	4.8
CO_2 ppm	7.5	5.5	6	5	6.5	8	6
Alk ppm	10	9	9	12	19	11	13
pH	5.5	5.8	5.8	5.9	6.3	6.1	6.2
S Cond μ mhos/cm	76	110	102	105	154	95	90
Cl ppm	28	31.5	35	36	43	30.5	30
Turb JTU	175	131	140	175	<395	<395	<395
Color CU	360	255	225	280	500	500	500
PO_4 ppm	0.17	0.18	0.05	0.03	0.0	0.0	0.52
NH_4 ppm	3.48	2.19	2	1.79	3.1	3.1	3.1
NO_3 ppm	0.0	0.0	0.0	0.0	0.171	0.161	0.017
Fe ppm	1.14	0.67	0.65	0.82	1.83	1.66	1.66
TSS ppm	59	45	45	65	121	131	133
TDS ppm	72	88	48	56	114	90	100
TDO ppm	70	58	40	42	58	52	42
TDI ppm	2	30	8	14	56	38	58
Chloro mg/l	0.0201	0.0067	0.0134	0.0201	0.0	0.0134	0.0067

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND
PINE ISLAND BAYOUS ON FEBRUARY 2, 1978, DURING FLOOD CONDITIONS

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	6	5	7	7	7	6.5	6
Bottom						6	6
O_2 ppm							
Surface	10.5	11.5	11.6	11.6	11.5	12.2	11.8
Bottom						11.8	11.6
% Sat							
Surface	87	93	99	99	98	100	98
Bottom						98	96
BOD ppm	2.4	2.9	3.1	2.6	2.9	3.3	3.8
CO_2 ppm	7.5	6	5	4.5	3.5	3.5	5
Alk ppm	20	5	8	19	16	13	12
pH	4.8	4.9	5.2	6.1	6.1	6	5.8
S Cond μ mhos/cm	57	78	86	128	85	82	74
Cl ppm	27.5	42	43	50	31	39	30.5
Turb JTU	97	106	114	128	160	140	120
Color CU	235	260	275	285	340	310	240
PO_4 ppm	1.46	0.69	1.69	1.74	0.29	0.8	0.25
NH_4 ppm	2.49	2.86	2.57	2.59	2.26	2.06	1.95
NO_3 ppm	0.0	0.0	0.0	0.031	0.0	0.025	0.0
Fe ppm	0.71	0.78	0.89	1.08	1.46	1.27	0.99
TSS ppm	10	29	41	51	82	67	38
TDS ppm	40	62	68	334	164	172	160
TDO ppm	34	60	56	290	92	128	94
TDI ppm	6	2	12	44	72	44	66
Chloro mg/l	0.0268	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND
PINE ISLAND BAYOUS ON FEBRUARY 25, 1978, DURING FLOOD CONDITIONS

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	14	11	12	12.5	11	13	11
Bottom						10	9
O_2 ppm							
Surface	8.7	8.7	9.5	9.1	9.5	12	11
Bottom						11.5	10.5
% Sat							
Surface	87	82	91	88	89	115	103
Bottom						105	94
BOD ppm	1.6	1.3	1	1.5	1.5	3.4	2.9
CO_2 ppm	8.5	7.5	6	9.5	4.5	4	7
Alk ppm	3	5	8	16	18	15	9
pH	4.2	5.8	6.1	5.7	6.1	5.9	5.9
S Cond μ mhos/cm	140	175	143	187	114	111	95
Cl ppm	51.5	50	45	52	37	31.5	30.5
Turb JTU	92	95	99	106	157	147	114
Color CU	240	230	225	240	360	350	260
PO_4 ppm	0.16	0.28	0.22	0.48	0.21	0.40	0.18
NH_4 ppm	3.1	2.66	2.76	2.66	2.66	2.76	2.19
NO_3 ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.008
Fe ppm	0.78	0.71	0.73	0.82	1.72	1.51	1.11
TSS ppm	19	20	36	40	111	87	44
TDS ppm	116	138	100	138	100	112	154
TDO ppm	70	84	58	46	26	38	50
TDI ppm	46	54	42	92	74	74	104
Chloro mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON MARCH 18, 1978, DURING HIGH FLOW

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	13	13	14.5	16	16.5	17	18
Bottom						15.5	14
O_2 ppm							
Surface	8.7	9.7	9.8	10.2	8.9	7.6	7.4
Bottom						6.5	6.7
% Sat							
Surface	85	95	99	107	94	81	81
Bottom						67	67
BOD ppm	3.1	4.5	3.4	3.7	3.3	2.7	2.7
CO_2 ppm	9.5	10.5	9	14	7	10.5	12
Alk ppm	12	8	11	30	30	29	25
pH	4.5	6	6.4	6.2	6.3	6.5	6.4
S Cond μmhos/cm	185	282	320	374	248	220	203
Cl ppm	97	84	92.5	106	61.5	55	52.5
Turb JTU	123	117	104	101	188	172	164
Color CU	380	465	300	280	480	440	400
PO_4 ppm	0.2	0.14	0.13	0.43	0.11	0.17	0.29
NH_4 ppm	3.9	3.38	2.8	3.02	2.36	2.86	3.02
NO_3 ppm	0.0	0.0	0.0	0.0	0.032	0.008	0.032
Fe ppm	1.77	1.72	1.46	1.31	3.25	2.22	1.98
TSS ppm	35	29	7	22	157	101	156
TDS ppm	130	218	246	256	250	412	200
TDO ppm	106	110	96	84	94	112	92
TDI ppm	24	108	150	172	156	300	108
Chloro mg/l	0.0201	0.0139	0.0201	0.0268	0.0201	0.0268	0.0268

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON APRIL 15, 1978, DURING LOW FLOW

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	17	18	18.5	20.5	22	23	23
Bottom						19	20
O_2 ppm							
Surface	4.3	5.3	5.8	7.4	6.3	8	9.5
Bottom						4.5	7.5
% Sat							
Surface	46	58	64	84	74	95	113
Bottom						50	85
BOD ppm	4.6	1.8	1.2	1.8	2.6	1.6	2
CO_2 ppm	14.5	13	9.5	10.5	5	4.5	3.5
Alk ppm	12	9	15	109	37	23	19
pH	5.4	5.6	5.8	6.5	6.4	6.7	6.5
S Cond μmhos/cm	1029	1039	735	800	41	23	20
Cl ppm	445	470	260	220	50	57	57
Turb JTU	99	64	54	71	114	99	99
Color CU	290	145	120	140	220	185	190
PO_4 ppm	0.06	0.34	0.28	4.1	0.0	0.13	0.17
NH_4 ppm	3.28	2.26	1.84	1.9	1.64	1.09	0.97
NO_3 ppm	0.0	0.032	0.117	1.735	0.161	0.032	0.032
Fe ppm	2.9	1.11	0.6	0.84	1.17	1.27	1.31
TSS ppm	22	16	6	55	75	30	22
TDS ppm	930	1016	358	466	190	212	120
TDO ppm	156	168	178	70	70	86	42
TDI ppm	774	848	180	396	120	126	78
Chloro mg/l	0.0134	0.0335	0.0402	0.0402	0.268	0.0871	0.0603

APPENDIX A (CONTINUED)

PHYSICOCHEMICAL CONDITIONS IN LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON MAY 11, 1978, DURING LOW FLOW

Parameter	Station 1	2	3	4	5	6	7
Temp C							
Surface	22	22	23	24.5	25.5	26	26
Bottom						26	25
O_2 ppm							
Surface	2.1	3.3	4.3	5	4.7	7.2	7.8
Bottom						7.5	6
% Sat							
Surface	25	39	51	61	58	90	98
Bottom						94	74
BOD ppm	4.4	4.2	1.8	1.8	2	2.2	2.2
CO_2 ppm	18.5	14	14.5	16.5	12	5.5	4.5
Alk ppm	35	34	34	176	50	25	26
pH	5.4	5.8	6	6.9	6.7	6.5	6.5
S Cond μmhos/cm	890	1470	1120	1480	625	216	200
Cl ppm	323	532	476	460	184	50	56
Turb JTU	106	90	49	90	101	117	120
Color CU	300	240	70	180	190	240	240
PO_4 ppm	0.22	0.17	0.2	2.47	0.06	0.17	0.13
NH_4 ppm	4.45	2.9	1.43	3.6	8.45	1.12	1.12
NO_3 ppm	0.0	0.206	0.097	0.2	0.161	0.135	0.157
Fe ppm	1.2	2.21	0.33	1.47	1.11	1.97	2.04
TSS ppm	22	16	5	39	54	54	64
TDS ppm	570	932	736	860	368	126	128
TDO ppm	152	130	100	114	96	56	62
TDI ppm	418	802	636	746	272	70	66
Chloro mg/l	0.0	0.0268	0.0	0.0134	0.0134	0.0	0.0

APPENDIX B

NUMBERS OF BENTHIC MACROINVERTEBRATES COLLECTED FROM LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON JUNE 17, 1977

Taxa	Station 1	2	3	4	5	6	7
Nematoda	3	11	4	2		20	4
Annelida							
Polychaeta	1						
Oligochaeta							
Nais variabilis	8	4			3	6	
Nais simplex				8			
Dero obtusa	2	8	2		1	1	
Dero nivea	2	4					
Aulophorus borellii	3						
Pristina longiseta leidyi	8	2					
Pristina breviseta	1	2			9	1	1
Aulodrilus pigueti	2				27	89	6
Tubifex sp.	23	1	17		9	16	4
Limnodrilus hoffmeisteri	179	200	67	37	195	674	162
Branchiura sowerbyi						27	17
Eclipidrilus sp.							2
Rhynchelmis sp.	1		5		1		
Hirundinea							
Bactracobdella picta	5		1	1			
Placobdella papillifera						1	
Helobdella elongata							4
Molluska							
Gastropoda							
Ferrissia sp.	10	2	13				3
Amnicola sp.			30	72	46	9	5
Pelecypoda							
Sphaerium sp.	1	3	27	10	4	12	5
Rangia cuneata						1	
Crustacea							
Mysidacea							
Taphromysis louisianae					2		
Isopoda							
Lirceus sp.		1	1				
Amphipoda							
Gammarus sp.		40	107		1		3
Decapoda							
Palaemonetes kadiakensis	1		7				
Insecta							
Ephemeroptera							
Hexagenia limbata	2	1	6			3	
Baetis sp.		2					

APPENDIX B (CONTINUED)

Taxa	Station 1	2	3	4	5	6	7
Caenis sp.		3		28	1		
Stenonema sp.			23				
Neocloeon sp.			1		2		
Odonata							
Dromogomphus spoliatus	1						
Dromogomphus spinosus		1	5				
Argia sp.			1				
Hemiptera							
Buenoa sp.	1						
Megaloptera							
Sialis sp.		6	15	6	1	1	2
Trichoptera							
Molanna sp.		2					
Phylocentropus sp.							3
Polycentropus sp.		4	4				
Coleoptera							
Dineutus sp.	1						
Hydrocanthus sp.	1						
Dubiraphia sp.			11	2			1
Stenelmis sp.		2	1				
Berosus sp.				1			
Diptera							
Larsia sp.			1				
Procladius sp.	48	34	4			7	5
Tribelos sp.	4						
Cryptochironomus sp.	1			4	1	1	
Polypedium sp.	3	4	69	79	2	4	7
Tanypus sp.	2	1	2				
Chironomus sp.	18	10		264	1	2	3
Stenochironomus sp.		1	7				2
Tanytarsus sp.		7	13	15	4	1	2
Cryptotendipes sp.		2			2		
Dicrotendipes sp.		1					
Conchapelopia sp.			15	4	2		2
Chironomini sp. A (Roback)			1				
Epoicocladius sp.			2			1	
Zenochironomus sp.			4				
Potthastia longimanus			1	3			
Clinotanypus sp.			1				
Micropsecta sp.				3			
Cladotanytarsus sp.				28	3		
Ablabesmyia sp.						2	
Pseudochironomus sp.							1
Psectrocladius sp.							1
Coelotanypus sp.						12	33
Chaoborus punctipennis	17					1	1

APPENDIX B (CONTINUED)

Taxa	Station 1	2	3	4	5	6	7
Tabanus sp.		1					
Palpomyia tibialis	1	13	5	8	3	2	2
Total Number Individuals	350	371	474	576	320	894	281
Total Number Taxa	29	29	34	20	22	24	26
Species Diversity ($\bar{d}$)	2.79	2.75	3.87	2.72	2.19	1.57	2.62

APPENDIX B (CONTINUED)

NUMBERS OF BENTHIC MACROINVERTEBRATES COLLECTED FROM LITTLE PINE ISLAND AND PINE ISLAND BAYOUS ON OCTOBER 15, 1977

Taxa	Station 1	2	3	4	5	6	7
Nematoda	11	3	2			3	2
Annelida							
Oligochaeta							
Nais variabilis		5			2	4	
Nais simplex				2		1	
Dero obtusa	2					109	32
Dero nivea	1						1
Dero digitata						3	
Aulophorus furcatus		101					
Pristina longiseta leidyi					1		
Pristina breviseta						3	
Pristina foreli						1	
Slavia appendiculata						1	1
Haemonais waldvogeli						16	
Tubifex sp.	144	1	5		29	39	
Limnodrilus hoffmeisteri	409	358	17	2	156	375	55
Branchiura sowerbyi						68	29
Aulodrilus pigueti			3		9	7	
Eclipidrilus sp.	1				3		
Rhynchelmis sp.	36						
Stylodrilus heringianus						2	1
Hirundinea							
Placobdella papillifera					1		
Helobdella elongata						1	1
Molluska							
Gastropoda							
Amnicola sp.			43	8	27	18	4
Physa sp.		7					
Gyraulus sp.		2	1				
Pelecypoda							
Sphaerium sp	10	10	20	1	3		1
Musculium sp.			1				
Eupera cubensis			19		1		
Lampsilis anodontoides					2	2	
Rangia cuneata							2
Crustacea							
Mysidacea							
Taphromysis louisianae					13	1	
Isopoda							
Lirceus sp.	1						

APPENDIX B (CONTINUED)

Taxa	Station 1	2	3	4	5	6	7
Amphipoda							
Gammarus sp.	1	1	7		1	10	
Corophium lacustre						12	6
Decapoda							
Procambarus simulans	1	1					
Palaemonetes kadiakensis					5		
Insecta							
Ephemeroptera							
Hexagenia limbata			74		11		
Caenis sp.			5	6		2	1
Callibaetis sp.						3	2
Libellula sp.	2						
Macrothemis sp.							3
Dromogomphus spoliatus				1			
Dromogomphus spinosus			2		1		
Hemiptera							
Limnogonus sp.			1				
Ranatra sp.					1		
Megaloptera							
Sialis sp.			7	1			
Trichoptera							
Polycentropus sp.			3	1			
Molanna sp.			1				
Coleoptera							
Dubiraphia sp.		1	6	1	3		
Berosus sp.				41			
Stenelmis sp.				3			
Diptera							
Chironomus sp.	4	57	1	2	1	4	4
Tanytarsus sp.	1	1	235	1	6	9	4
Tanypus sp.		97					
Polypedilum sp.	2	4	17	8	5	7	4
Conchapelopia sp.		2	4			4	2
Procladius sp.		2	4				1
Dicrotendipes sp.		61	24	1		29	2
Parachironomus sp.		3				1	
Cladotanytarsus sp.			7		1	2	
Cryptotendipes sp.			8			6	
Larsia sp.			1				
Polypedilum (Fallax) sp.			4			2	
Cryptochironomus sp.			1	1		3	
Stenochironomus sp.			1	2	1		
Ablabesmyia sp.			3				
Paratendipes sp.					5	1	
Coelotanypus sp.						11	8

APPENDIX B (CONTINUED)

Taxa	Station 1	2	3	4	5	6	7
Pedionomus beckae						1	
Cecidomyiidae	1						
Chaoborus punctipennis	4						1
Tabanus sp.	1						
Palpomyia tibialis	2	19	1		3	1	1
Total Number Individuals	604	736	528	82	291	762	169
Total Number Taxa	19	20	32	17	25	36	25
Species Diversity ($\bar{d}$)	1.61	2.44	3.13	2.75	2.71	2.88	3.23

APPENDIX B (CONTINUED)

NUMBERS OF BENTHIC MACROINVERTEBRATES
COLLECTED FROM LITTLE PINE ISLAND AND
PINE ISLAND BAYOUS ON FEBRUARY 25, 1978

Taxa	Station 1	2	3	4	5	6	7
Hydrozoa							
Hydra sp.							1
Turbellaria							
Phagocata morgani							1
Nematoda	5		1	2	9	5	3
Annelida							
Oligochaeta							
Nais variabilis			1			1	
Nais simplex		2					
Dero nivea	2	4	1			16	8
Pristina breviseta					3		
Dero obtusa						2	
Slavina appendiculata		1					
Haemonais waldvogeli						1	
Tubifex sp.	213		29			5	
Limnodrilus hoffmeisteri	304	444	219	549	141	370	453
Branchiura sowerbyi						38	20
Aulodrilus pigueti							1
Peloscolex multisetosus	88	1				19	24
Enchytraeus sp.	1						
Eclipidrilus sp.	4	5	4		17	3	2
Rhynchelmis sp.	26			1	1		
Hirundinea							
Helobdella elongata						2	3
Molluska							
Gastropoda							
Amnicola sp.			4	5		7	8
Physa sp.		7				1	1
Pelecypoda							
Sphaerium sp.	5	2	2			8	8
Pisidium sp.						1	3
Eupera cubensis							2
Uniomerus sp.						1	1
Crustacea							
Mysidacea							
Taphromysis louisianae						3	2
Isopoda							
Lirceus sp.					1	3	7
Asellus sp.			2		1	1	18
Amphipoda							
Crangonyx sp.	5	9	2		1		
Gammarus sp.			1	1	9	5	2

APPENDIX B (CONTINUED)

Taxa	Station 1	2	3	4	5	6	7
Corophium lacustre						7	14
Decapoda							
Procambarus simulans			1				
Hydracarina						12	2
Insecta							
Plecoptera							
Perlesta placida			4	5			
Ephemeroptera							
Hexagenia limbara			1			6	1
Caenis sp.			2	19		13	16
Stenonema sp.				1			
Odonata							
Libellula sp.				2			
Macromia sp.				1			
Argia sp.		2	1	1			
Dromogomphus spinosus				2			1
Tauriphila sp.			1				
Trichoptera							
Polycentropus sp.							2
Cheumatopsyche sp.				1			
Oecetis inconspicua							2
Agraylea sp.						1	
Coleoptera							
Stenelmis sp.		1					
Berosus sp.				6			
Dubiraphia sp.						1	
Hydroporus sp.						2	1
Diptera							
Chironomus sp.				7		1	1
Tanytarsus sp.	15	3	3	4	1	3	1
Cryptochironomus sp.	1		1	3		12	8
Psectrocladius sp.	6	8	4	2	1		
Dicrotendipes sp.	1	3		5		17	19
Procladius sp.	2	8	7	5		20	24
Polypedilum sp.		5	2	65	4	9	13
Conchapelopia sp.		1				1	
Tanypus sp.			2				
Ablabesmyia sp.			2			7	8
Paratendipes sp.			1				
Cladotanytarsus sp.				1	1		
Labrundinia sp.				1			
Paralauterborniella sp.				2	11		
Paracladopelma sp.					1	1	
Coelotanypus sp.						4	
Polypedilum fallax						3	1
Clinotanypus sp.						1	

APPENDIX B (CONTINUED)

Taxa	Station 1	2	3	4	5	6	7
Cecidomyiidae					1		1
Chaoborus punctipennis						7	7
Tabanus sp.	1	1	1				
Palpomyia tibialis	4	13	7	1	3	4	2
Tipula sp.		1					
Simulium sp.				103			
Total Number Individuals	683	521	306	795	206	625	693
Total Number Taxa	17	20	27	26	17	41	40
Species Diversity ($\bar{d}$)	2.13	1.16	1.94	1.76	1.92	2.85	2.49

APPENDIX B (CONTINUED)

NUMBERS OF BENTHIC MACROINVERTEBRATES
COLLECTED FROM LITTLE PINE ISLAND AND
PINE ISLAND BAYOUS ON APRIL 15, 1978

Taxa	Station 1	2	3	4	5	6	7
Hydrozoa							
Hydra sp.			4				
Turbellaria							
Phagocata morgani	1		1				
Nematoda	4		2			2	5
Annelida							
Oligochaeta							
Nais simplex			1				
Dero nivea	9		1		1	13	1
Pristina breviseta	7						
Pristina longiseta leidyi			1	1			
Pristina aequiseta						2	
Tubifex sp.	551	17	32		9	21	4
Limnodrilus hoffmeisteri	433	283	163	1	101	495	358
Peloscolex multisetosus	53	1	3			9	8
Branchiura sowerbyi					2	7	3
Eclipidrilus sp.	2			1			14
Rhynchelmis sp.	22		10				2
Stylodrilus heringianus						3	
Branchiobdellidae		1					
Hirundinea							
Dina sp.	1						
Helobdella elongata						3	
Molluska							
Gastropoda							
Amnicola sp.			125	28	38	18	7
Physa sp.			1				
Ferrissia sp.			4				
Pelecypoda							
Sphaerium sp.		1	9	7	1	3	3
Lupera cubensis			1				1
Musculium sp.			1				
Rangia cuneata							2
Unidentified Unionidae						1	
Crustacea							
Mysidacea							
Taphromysis louisianae					1	5	
Isopoda							
Lirceus sp.	2	1	4		1	8	
Asellus sp.						4	

APPENDIX B (CONTINUED)

Taxa	Station 1	2	3	4	5	6	7
Amphipoda							
Crangonyx sp.	59	8					
Gammarus sp.			119	2	20	11	1
Corophium lacustre						1	1
Decapoda							
Palaemonetes kadiakensis			2		3		
Unidentified Astacidae					2		
Hydracarina						1	
Insecta							
Ephemeroptera							
Hexagenia limbata	2	2	37			3	3
Caenis sp.			35	5		2	2
Stenonema sp.		4	5				
Odonata							
Argia sp.			1				
Dromogomphus spinosus			4				
Didymops sp.			1				
Hemiptera							
Unidentified Corixidae		1					
Megaloptera							
Sialis sp.			1	2			
Trichoptera							
Cyrnellus sp.			1	2			
Oecetis inconspicua			2				
Coleoptera							
Dubiraphia sp.			5	1	1		
Hydroporus sp.			1				
Diptera							
Procladius sp.	126	41	3			5	8
Dicrotendipes sp.	20	10	76				
Chironomus sp.	68	18		4	2	1	
Parachironomus sp.	2	3	2				
Tanytarsus sp.	34	20	376	7	10	2	
Cryptochironomus sp.	6	24	3	10	11	9	5
Polypedilum sp.	4		148	6	3	3	1
Ablabesmyia sp.	1		13	1	1	4	13
Paralauterborniella sp.	1						
Cladotanytarsus sp.	1		494		1	2	
Stictochironomus sp.		2					
Conchapelopia sp.		1	1				
Stenochironomus sp.			2				
Micropsectra sp.			21				
Paracladopelma sp.				1			
Psectrocladius sp.					4	5	
Epoicocladius sp.						1	

APPENDIX B (CONTINUED)

Taxa	Station 1	2	3	4	5	6	7
Palpomyia tibialis	6	2	21	5	3	7	1
Chaoborus punctipennis						11	
Total Number Individuals	1415	440	1737	84	215	662	443
Total Number Taxa	24	19	42	17	20	31	21
Species Diversity ($\bar{d}$)	2.54	2.10	3.29	3.30	2.70	1.93	1.44

APPENDIX C

WATER QUALITY MONITORING PROCEDURES

Water quality monitoring stations were selected near the streams entrance into and exit from the preserve units. Additional stations were established in the interior of the units where access was available and below suspected or known sources of pollution. Stations located below known pollutional effluents were located far enough downstream to allow mixing of the effluent with stream water. All stations in the same stream were sampled on the same day in order to establish downstream trends.

Water for chemical analyses was collected by submersion of clean 300 ml BOD bottles after being rinsed with water from the collecting site. The bottles were filled completely avoiding air bubbles. Six BOD bottles were required for determination of all field and laboratory tests at each station. Two bottles were used for measurements of pH, alkalinity and carbon dioxide in the field. Temperature and dissolved oxygen were also determined in the field using a YSI Model 57 Oxygen Meter. Four bottles were stored in a dark container and returned to the laboratory. All remaining tests were run immediately upon return to the laboratory that same day.

Water for bacteriological analyses was collected in sterile 100 ml bottles and stored under ice.

All reagents used in the field were stored in amber glass bottles out of direct sunlight. Different glassware and pipettes were used for each test run in the field.

All methods of measurement and equipment used are listed in the METHODS section in PART I of this report. The required chemicals and

glassware with "cookbook" procedures for each test are given in Standard Methods For the Examination of Water and Wastewater (American Public Health Association, 1975) and Water and Wastewater Analysis Procedures (Hach Chemical Company, 1975).